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ATMOSPHERIC EFFECTS UPON LASER BEAM PROPAGATION: AN ANNOTATED BIBLIOGRAPHY

INTERIM TECHNICAL REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Results of a literature search on the effects of normally occuring atmospheric molecules, aerosols and turbulence on the propagation of low power lasers is presented in a thoroughly cross referenced bibliography. Included are references to theoretical, experimental and modeling studies that could be relevant to developing models (and their required data bases) for the purpose of establishing comprehensive safety standards for laser illumination of the human eye. Two separate computerized literature searches (with extensive manual editing) were utilized, as well as other sources, to locate these references. Current and planned efforts by several key researchers are also described.

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1
INTRODUCTION

In order to establish comprehensive laser eye safety standards, it is necessary to consider the effects of the atmosphere. Molecules and aerosols in the atmosphere will absorb and scatter laser radiation, while turbulence in the atmosphere will cause spatial and temporal redistribution of the beam's energy at the target plane. This bibliography attempts to compile theoretical and experimental information pertaining to all these effects*.

The bibliography addresses the low power laser operating in the ultraviolet, visible, or infrared spectral regions (i.e., roughly 0.2 to 11 μm), over an arbitrary atmospheric path (i.e., horizontal, vertical or slant path) up to 100 km altitude. Only normal atmospheres (i.e., no countermeasure smoke** or nuclear perturbation) were considered. Multiple scattering effects** (except relating to turbulence), and nonlinear propagation effects such as thermal blooming, saturation bleaching, and aerosol vaporization or alteration were not addressed.

References were also included in the bibliography to papers containing information on peripheral areas such as the condition and composition of the atmosphere, the optical properties of aerosol materials, and the precise location of various laser lines (since they would be required in line-by-line modeling). However, because of the breadth and many facets of these subjects, it was not possible within the scope of this effort (i.e., approximately three man months were allocated to this

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*This information will be evaluated in a subsequent report, in order to establish the state-of-information on these effects, and to recommend analytical models to be employed for setting more comprehensive laser eye safety standards.

**References to these subjects were included when readily available.

task) to cover the material to the same depth. For example, there is a wealth of information on the molecular, aerosol and turbulence composition of the atmosphere as a function of altitude, locale, time of day, time of year, etc. In these cases, an in-depth survey was not deemed warranted and only the principal papers were referenced. The resulting bibliography is believed to be comprehensive regarding experimental measurements on these effects and their modeling.

A summary of the bibliography and the approach taken in compiling the information is given next (Section 2). This is followed by a topic index (Section 3) to provide a finer subdivision of subject areas than the ten categories (see Table 1) allow. Discussions with key researchers regarding their current and planned work is given in Section 4, followed by the annotated bibliography in Section 5.

2
SUMMARY AND APPROACH

A total of 1050 citations to reports and papers on atmospheric effects are given in the bibliography; along with approximately fifty additional references to texts. Over eighty percent of these citations are annotated. They are arranged in ten categories as shown in Table 1. Two thirds of these citations were from journal articles and most of the others were reports. A cross reference index is provided to delineate those citations relating to a number of topic areas (see Table 2). Discussions with a number of key researchers in the field indicated several interesting new measurements and modeling efforts (see Section 4).

A number of sources were utilized to compile the information presented in this bibliography, including two different computerized searches, several earlier technical reviews of the subject, and discussions with experts in the field. The most important source was the Lockheed computerized bibliographic search service called the DIALOG Information Retrieval Service [2-1]. Basically this system employs a combination of user-specified key words or phrases to identify reports and articles of interest. The computer prints the number of papers it has found with each key word, and (at the user's command) each paper's reference mate ial. For journal articles, this reference material includes the title, authors, journal name, volume, number, date and page numbers; and for technical reports, the corporate author, report number and in most cases, ordering information (eg., NTIS number). The user can also direct the computer to print if available, the complete abstract of each paper.

The DIALOG search was performed for Nichols Research Corporation by the Infrared Information Analysis (IRIA) Center at ERIM under the direction of their experts in the field of atmospheric effects and information retrieval, A. J. LaRocca and J. Livisay. At their suggestion,

TABLE 1

BIBLIOGRAPHY SUMMARY
Atmospheric Effects on Laser Beam Propagation

CATEGORY	TOTAL NUMBER OF CITATIONS	JOURNALS	REPORTS	SYMPOSIA	OTHER	NUMBER ANNOTATED	PAGE NUMBER
1. Molecule Effects	146	60	69	11	6	120	16
2. Molecule Conditions	35	28	6	0	1	28	32
3. Aerosol Effects	142	78	45	18	1	98	36
4. Aerosol Conditions	190	158	25	5	2	122	52
5. Turbulence Effects	344	235	73	30	6	309	69
6. Turbulence Conditions	46	32	6	6	2	35	110
7. Field Measurements (Molecule & Aerosol Effects)	206	162	35	7	2	191	115
8. General	27	5	17	5	1	25	128
9. Biological Effects	19	12	5	2	0	12	132
10. Texts	47	-	-	-	-	19	134
TOTAL	1155	770	281	84	21	959	

the search was made on the SCISEARCH and COMPENDEX data bases with the keyword* combination: LASER and (PROPAGAT or TRANSMISS or TURBULEN) and not BLOOM. SCISEARCH is a multi-disciplinary index to the literature of science and technology prepared by the Institute for Scientific Information from about 2600 journals. COMPENDEX contains all the information in "The Engineering Index" which covers about 1800 journals, 1000 conference or symposia proceedings, and selected government reports and books. Using the above key word combination, the computer found 2589 papers from SCISEARCH, and 1661 papers from COMPENDEX. An earlier trial run with the same key word combination appended by: (and MODELS or EXPERIM), produced only 147 and 256 papers from SCISEARCH and COMPENDEX respectively.

The second computerized search was performed by NTIS on "Atmospheric Effects on Laser Beams" for the time periods from 1964 through 1974 [1023], and 1975 through September 1978 [1024]. Both of these searches required considerable manual review to exclude papers that were not pertinent to the present problem (i.e., less than 20% of the papers were pertinent). For example, there were a large number of papers on laser fusion, laser operation, flow diagnostics, non-linear effects, and experimental or program planning. In order to eliminate such unwanted references, it was necessary to read all the titles and many of the abstracts. The abstracts of all those deemed pertinent were read in detail to extract one or two sentences of concentrated annotation information, assign it to one of several categories (see Table 1), and decide whether to order the paper.

An explanation is required for some of the categories shown in Table 1. The categories ending in "Conditions" generally refer to the state of the atmosphere, such as the number distribution of various molecule and aerosol species, atmospheric turbulence levels, etc. However, ancillary information is also included in these 'conditions categories,' such as the index of refraction of typical aerosol materials, the spectral positions of laser lines (in molecular effects), etc. Field

*Using only the first letters of a word locates all forms of the word (eg., TURBULEN will give TURBULENT and TURBULENCE).

measurements of molecular and aerosol effects were put into another category, since these effects are very difficult to separate in the field. A general category was included to cover papers covering in detail two or more of the previous categories. A few articles were found on biological effects, so they were included for completeness in a separate category. Finally, Category 10 delineates the more important texts that have been published on this topic.

Several other sources of references were utilized during the survey, notably other earlier surveys and reviews. These included excellent texts by Zuyev [1096]*, McCartney [1028] and Strohbehn [1085]; an IRIA-IRIS Index to the DoD Conferences on Laser Technology [2-2]**, the AGARD Conference on Optical Propagation in the Atmosphere [2-3], and review articles by Fante [627], Prokorov [792] and Meredith [1019].

*Single number in brackets indicate citations in the Bibliography (Section 5).

**Double numbers refer to the references at the end of the report.

3
TOPIC INDEX

In an attempt to improve the usefulness of this bibliography, all the references were numbered, indexed* and cross referenced. This index indicates all those references that pertain to a number of different categories that were deemed to be of primary interest (see Table 2). These include the general type of report, if a particular laser was investigated, and several topics relating primarily to molecule, aerosol or turbulence effects. Articles that give a detailed treatment of several areas in any one of these topic areas, are indexed under that general topic area.

*This indexing was based only on the title and the annotation, since a thorough review of these references will not be completed until the next phase of this contract.

TABLE 2

TOPIC INDEX

REPORT TYPE

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TURBULENCE TOPICS (Continued)

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Index of Refraction Structure Function:	853,856-958,864-866,869,872-876,880,882,884,885,389,890,892,895-897,1063
Temperature Structure Function:	859,867,868,870,876,877,881,884,891,894
Other Turbulence Statistics (Velocity, etc.):	855,860,861,863,888,894
Altitude Dependence:	853,857,858,861,864,866,867,873,874,877,880,890,952-954,959,983,984,1003

LASERS

Argon:	55,774,838,978
Carbon Dioxide:	1,6-8,10,18,27,36,40,44,45,48,50,56,62,76,80,91,92,94,97,98,108,109,114,117,119,121,123,139,165,187,202,242,243,269,301,310,520,538,608,609,662,706,715,750,795,796,809,830,833,851,909-911,945,951,955,956,960,972,975,986,987,1032,1040,1042,1045
Carbon Monoxide:	42,47,60,64-67,69-72,85,93,102-105,139,948,955
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Helium:	43,132,979
Krypton:	55
Nd-Yag:	10,33,172-174,201,202,242,926,928,955
Neon:	55
Nitrogen Dioxide:	95
Ruby:	52,57,202-274,805,806,912,968,979,986
Other:	185,947,1049

4
DISCUSSIONS WITH RESEARCHERS IN THE FIELD

Various key researchers in the field were contacted by telephone to inquire about their latest work and future plans. New references to several very recent and soon-to-be published papers were gathered that will be included in the reference list to this report, but not in the bibliography section.

Robert A. McClatchey: AFGL is planning to continually upgrade the AFGL line parameter tape [164] as new information becomes available; no changes to the structure of the code LASER [79] are planned. They are also developing fundamental aerosol models (that can be employed in LASER), including such effects as particle growth and complex refractive index changes with relative humidity, effects of wind speed and type of air mass. They are trying to find some physical measurement to indicate the type of air mass present, (eg., maritime aerosols often are present in the heart of the continent and vice versa). The OPAQUE data will be used to validate these fundamental models rather than to develop empirical models. The analysis of the OPAQUE data just started about six months ago, so no reports are out on it yet. A report is available that describes the experiment and presents some preliminary results [4-1].

Robert W. Fenn: AFGL is preparing a report on a statistical analysis of the OPAQUE measurements of visible and infrared transmission, meteorological and natural illumination for the winter [4.2]. This does not include any laser propagation data. Other reports will be prepared on analyses for other seasons.

James A. Dowling: NRL will be making more absolute laser transmission (DF, CO_2, Nd Yag and HeNe) and FTS relative transmission measurements during March at the White Sands HELSTF (High Energy Laser Standard Test

Facility) 6.5 km path. In May they are planning the same measurements at the San Nicholas Island 4 km path. Transmissometer measurements will be done at the same time and over the same path. They are also planning similar measurements in late summer 1979 in support of: 1) the Navy Optical Signatures Program, 2) the A.S.L. battlefield aerosol environment program, and 3) measurements in Germany. They are also planning some measurements on turbulence effects at 3.8 μm. The high spatial and temporal resolution irradiance structure will be recorded simultaneously with the temperature structure statistics of the atmosphere over a 6.5 km at White Sands.

Kenneth O. White: ASL has continued their measurements on Deuterium depleted water [133] to consider the pressure dependence of the absorption [4-3]. They found the ratio of foreign-to-self contributions a factor of ten less than measured by Burch. They have also made a series of measurements on the transmission of an HF laser (2.7 - 3.1 μm) at five temperatures from ambient to -18°C, and at various ratios of self-to-foreign gases [4-4]. Significant differences from the AFGL tape [164] were observed. They are currently calibrating a spectrophone with this data to extend the measurement to -50°C. They are also planning to measure the water vapor continuum with a CO_2 laser and to determine the dimer contribution. They are also planning laser absorption measurements in the 3-5 and 8-12 μm region on the battlefield gases.

Barry S. Katz: Naval Surface Weapons Center is involved in modeling the performance of optical systems (including lasers) as it is affected by a statistical marine atmosphere, based on weather ship data using simple expressions assuming single scattering [4-5]. They model the turbulence effects with the models of Yura and Fried, which give the beam spread and tilt angle. Initial beam divergence and jitter are also modeled [4-6].

Robert E. Roberts: He has done no more work at IDA on modeling the water vapor continuum, but is currently involved with aerosol effects on optical systems. In applying the OPAQUE measurements and their statistics to slant path situations, he found large differences with the LOWTRAN predictions.

Douglas R. Woods: He has not published anything in the field recently, suggested two reports [4-7,4-8] he found recently.

Ronald K. Long: OSU has recently developed a long path (1 km) Fourier Transform Spectrometer which has a resolution of 0.05 cm^{-1} over the region from 800 to 5000 cm^{-1}, and plans to measure water vapor absorption. They also hope to measure ozone absorption (both 9.6 μm band and overtones) with the instrument in support of the ATMOS experiment planned for the Space Shuttle. Their spectrophone is currently idle, and the FTS is not fully committed.

Frederick G. Smith: Science Applications, Inc. will be starting an analysis of the European aerosol statistics measurements by the Atmospheric Sciences Laboratory in conjunction with the OPAQUE program. These balloon borne measurements were made by R. Pennick and J. D. Lindberg at ASL. There was a recent meeting in Germany in which the U.S. and the Netherlands presented papers on aerosols.

It is his feeling that the molecular effects on the propagation of DF and CO_2 lasers is well understood, with the possible exception of the temperature effects of the continuum and the ratio of the self-to-foreign broadening. For the CO laser there are still questions regarding the line shape, the existence of a 5 μm continuum, and the accuracy of the line parameters in this region, but to his knowledge no one is pursuing these problems.

Robert E. Hufnagel: Perkin Elmer has not developed any new models for the state of high altitude turbulence, since his 1974 model [873] fits the most recent measurements quite well. A model based more on physics (his is an ad hoc model), was recently developed by the Aeronomy Laboratory at NOAA [4-9]. The topic of ground level turbulence is covered well by Reference 1077.

5
BIBLIOGRAPHY

1. MOLECULE EFFECTS

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5. TURBULENCE EFFECTS

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538. R. E. Betkher, T. O. Viitman and Kh. V. Khinrikus, "Experimental Investigation of Fluctuations of a Laser Beam in an Atmospheric Path," Sov. J. Quant. Electron., Vol. 5, No. 9, p. 1074. [Measurements of transmission at 0.63 and 10.6 μm over a 5 km atmospheric path were used to calculate fluctuations of beam width, position and intensity. Both wavelengths gave similar results.]

539. L. R. Bissonnette, A Semi-Empirical Closure Theory of Optical and IR Wave Propagation in Turbulent Media, Rept. No. DREV-R-708-74, Issued by: Defence Res. Establ., Valcartier, Quebec, Avail. from NTIS. [Equations are written in a format with which the important mechanisms contributing to light scintillation are clearly identified to specific mathematical terms.]

540. L. R. Bissonnette, "Log-Normal Probability Distribution of Strong Irradiance Fluctuations: An Asymptotic Analysis," AGARD Conf. Proc. #183, Lyngby, Denmark, 27-31 December 1975 (AD-A028 615). [Shows that the irradiance variance diverges to infinity if the irradiance probability distribution is everywhere log-normal. Using the same asymptotic solutions, it is shown that the irradiance variance tends to unity if, alternately, the wave amplitude has a normal distribution in the saturation region.]

541. L. R. Bissonnette, Probability Distribution and Asymptotic Variance of Strong Irradiance Fluctuations of Optical Waves in Turbulent Media, Rept. No. DREV-R-4042/75, Defence Res. Establ., Valcartier, Quebec, October 1975 (AD-A021 126/8ST). [The asymptotic solutions for the first- and second-order statistical moments of the amplitude of a plane optical wave propagating in a turbulent atmosphere are derived from Maxwell's equations.]

542. B. D. Borisov, Investigation of the Angle Fluctuation of Incoming Laser Emissions in the Near-Earth Layer of the Atmosphere, Rept. No. NASA-TT-F-12380, July 1969 (N69-31342).

543. G. K. Born, "Phase-Front Distortion of a Laser Beam by Atmospheric Turbulence," Phys. Lett. A, Vol. 33A, No. 6, p. 397, November 1970. [The distortion of the phase front of a laser beam propagating through the turbulent atmosphere is determined under conditions of strong turbulence.]

544. G. K. Born, "Phase-Front Distortion of Laser Radiation in a Turbulent Atmosphere," Appl. Opt., Vol. 14, No. 12, p. 2857, December 1975. [Color photographs (0.5 m sec. exposure) are taken of the center section of the fringes (60 mm dia.). The phase structure function and arrival angle fluctuations are interpreted in terms of turbulence strength and structure.]

545. G. K. Born, et al., "Phase-Front Deformation of Laser Beams by Atmospheric Turbulence," Prog. of 1971 Spring Meeting of OSA, 5-8 April 1971, Tucson, AZ. [Phase-front distortion of laser beams was studied over horizontal paths from 0.5 to 2 km, 2.5 m above ground, under conditions of inversion at high enough wind speeds (1-5 m/s).]

546. G. M. B. Bouricius and S. F. Clifford, "Experimental Study of Atmospherically Induced Phase Fluctuations in an Optical Signal," JOSA, Vol. 60, No. 11, pp. 1484-1489, November 1970. [Measured time-lagged structure function compares well with Tatarski's theory, but not with Bertolotti's measurements.]

547. H. J. Breaux, Correlation of Extended Huygens-Fresnel Turbulence Calculations for a General Class of Tilt Corrected and Uncorrected Laser Apertures, BRL Interim Tech. Rept. 600, May 1978. [Correlates Strehl ratio with effective strength of turbulence; good agreement with measurements. Develops an analytical approximation for coherence length integral for slant paths.]

548. H. Bremmer, "General Remarks Concerning Theories Dealing with Scattering and Diffraction in Random Media," Radio Sci., Vol. 8, pp. 511-534, June 1973.

549. E. Brookner, "Atmospheric Propagation and Communication Channel Model for Laser Wavelengths," IEEE Trans. Comm. Tech., Vol. COM-18, pp. 396-416, August 1970. [A review of a major part of the extensive literature pertaining to theoretical and experimental results on the propagation of laser signals in the atmosphere is given.]

550. W. Brown, "Second Moment of a Laser Beam in a Random Medium," JOSA, Vol. 61, No. 8, pp. 1051-1059, August 1971. [Quantitative results are given for a gaussian beam. The ensemble-averaged distribution of irradiance remains gaussian and gives the e-folding radius of this distribution.]

551. W. Brown, "Moment Equations for Waves Propagated in Random Media," JOSA, Vol. 62, No. 1, pp. 45-54, January 1972. [This paper applied a diagrammatic technique and shows that the partial differential equations obtained by Tatarski, Beran, and Ho for the 1st, 2nd, and 4th statistical moments of a wave propagating in a random medium are special cases of a general partial differential equation satisfied by the mth moment when the refractive index inhomogeneities are sufficiently weak.]

552. W. Brown, "Fourth Moment of a Wave Propagating in a Random Medium," JOSA, Vol. 62, No. 8, pp. 966-971, June 1972. [Starting with a partial differential equation, the general properties of the 4th moments of an initially plane wave and then present numerical results for a two-dimensional plane wave by applying a diagrammatic technique.]

553. A. L. Buck, "Effects of the Atmosphere on Laser Beam Propagation," Appl. Opt., Vol. 6, No. 4, pp. 703-708, April 1967. [An experimental study of horizontal laser beam propagation over paths up to 145 km long was made in which beam diameter and shape, intensity fluctuations, and optical phase distortion were measured.]

554. J. L. Bufton and L. S. Taylor, "Laser Beam Scintillation Beyond the Turbulent Atmosphere, A Numerical Computation," Appl. Opt., Vol. 15, No. 10, p. 2534, October 1976. [Scintillation of laser beams propagating through atmospheric turbulence is studied using the "so-called" extended Huygens-Fresnel method with a numerical integration technique. Results are compared with another gaussian beam propagation theory.]

555. F. Bunkin and K. S. Gochelashvily, "Spreading of a Light Beam in a Turbulent Medium," Radiophys. Quant. Electron., Vol. 13, pp. 811-821, July 1970. [Theoretical analysis based on method of smooth perturbations, including saturation effects.]

556. R. G. Buser, "Interferometric Determination of the Distance Dependence of the Phase Structure Function for Near-Ground Horizontal Propagation at 6328 A," JOSA, Vol. 61, No. 4, p. 488, April 1971 (AD 736 557). [Experimental results are compared with the predictions of the 2/3 power law; it is found that the unmodified Obukhov-Kolmogorov theory does not describe the results correctly, and a considerably lower value for the exponent is observed.]

557. S. J. Campanella and S. B. Sample, A Study of Laser Wave Scattering Due to Refractive Index Perturbations in the Propagating Medium, Final Report, 5 October 1965 - 15 August 1966, NASA-CR-65553 (N66-39966).

558. F. P. Carlson and A. Ishimaru, "Propagation of Spherical Waves in Locally Homogenaous Random Media," JOSA, Vol. 59, No. 3, pp. 319-327, March 1969. [The propagation of spherical waves in a turbulent medium is considered. In particular, the case of non-stationary statistics is examined in general and then applied to the specific case of vertical propagation in the atmosphere. Analysis uses the Rytov approximation and the perturbator technique of J. B. Keller.]

559. T. Chiba, "Beam Spread of Laser Light Propagating Through the Atmosphere," Electron. & Commun., Vol. 54, No. 11, p. 90, November 1971. [Propagation experiments using a He-Ne laser beam were carried out on a 1380 m path. The photographs of beam spread show good agreement with the results of the theoretical work.]

560. T. Chiba, "Spot Dancing of the Laser Beam Propagated Through the Turbulent Atmosphere," Appl. Opt., Vol. 10, No. 11, pp. 2456-2461, November 1971. [An analysis of this problem is made by using the Kolmogorov structure function of the refractive index and geometrical optics. Laser propagation experiments are carried out over 480 m and 1380 m paths. Satisfactory agreement.]

561. T. Chiba and Y. Sugiura, "Spot Dancing of Laser Beam in Atmospheric Propagation," Electron. & Commun., Vol. 54, No. 2, p. 89, February 1972. [Analysis uses Kolmogorov's structure function. Experiments carried out over 480 m and 1380 m outdoor paths show satisfactory agreement.]

562. T. Chiba and Y. Sugiura, "Characteristics of Propagation of a Laser Beam Through the Turbulent Atmosphere, I, Spot Dancing," NHK Tech. J., Vol. 24, No. 4, p. 41, 1972. [Investigated both theoretically and by experimental measurements over 480 and 1380 m paths. Good agreement.]

563. T. Chiba and Y. Sugiura, "Characteristics of Propagation of a Laser Beam Through the Turbulent Atmosphere, II, Beam Spread," NHK Tech J., Vol. 25, No. 1, p. 42, 1973. [Average irradiance distributions of a beam are measured by a photographic method. The theoretical value of the effective beam size shows good correspondance with the experimental value.]

564. T. S. Chu, "On the Wavelength Dependence of the Spectrum of Laser Beams Traversing the Atmosphere," Appl. Opt., Vol. 6, No. 1, p. 163, 1967. [Investigated intensity fluctuations of three lasers (0.63, 3.51 and 10.6 μm).]

565. S. F. Clifford, "Temporal-Frequency Spectra for a Spherical Wave Propagating through Atmospheric Turbulence," JOSA, Vol. 61, No. 10, pp. 1285-1292, October 1971. [Spectra, calculated for spherical waves, reveal contributions at higher frequencies for amplitude scintillations, nearly identical phase results, and a phase-difference spectrum with no nulls, in contrast with the plane-wave results.]

566. S. F. Clifford, G. M. B. Bouricius, G. R. Ochs and M. H. Ackley, "Phase Variations in Atmospheric Optical Propagation," JOSA, Vol. 61, No. 10, pp. 1279-1284, October 1971 (COM-73-10119-19). [Using a He-Ne laser on a 70 m propagation path, the authors measured the optical phase variations at four different spacings. Measured angle of arrival spectrum.]

567. S. F. Clifford, G. Ochs and R. S. Lawrence, "Saturation of Optical Scintillation by Strong Turbulence," JOSA, Vol. 64, No. 2, pp. 148-154, February 1974. [Physical model to calculate variance and covariance of irradiance fluctuations in non-linear region. Develops equation for short term modulation transfer function.]

568. S. F. Clifford and H. T. Yura, "Equivalence of Two Theories of Strong Optical Scintillation," JOSA, Vol. 64, pp. 1641-1644, 1974. [Develops expressions for log-amplitude covariance function in strong turbulence. Develops physical model for saturation.]

569. E. Collett and R. Alferness, "Depolarization of a Laser Beam in a Turbulent Medium," JOSA, Vol. 62, No. 4, pp. 529-533, April 1972. [The correlation function is evaluated for a turbulent medium which is characterized by (a) a gaussian spectrum or (b) a Kolmogorov spectrum.]

570. E. Collett, R. Alferness and T. Forbes, "Log-Intensity Correlations of a Laser Beam in a Turbulent Medium," Appl. Opt., Vol. 12, No. 5, p. 1067, May 1973 (AD 766 544/1). [The log-intensity correlation for any two points in the cross section of a collimated gaussian laser beam is calculated in the geometrical optics approximation. The log-intensity correlation is found to be a function of more than the separation distance between the two points.]

571. S. A. Collins, Investigation of Laser Propagation Phenomena, Final Rept. 1 January 1971 - 28 February 1972, Rept. No. ESL-3163-3, April 1972 (AD 746 053). [Efforts described are concentrated in three main areas: the examination of proper averaging times required for specific propagation experiments; the calculation of theoretical curves predicting results of various experiments along slant paths; and the calculation of predicted results for the temporal spectra of particular atmospheric effects.]

572. S. A. Collins and D. D. Duncan, Investigation of Laser Propagation Phenomena, Final Tech. Rept. No. ESL-3432-7, December 1973 (AD 775 738/8). [Temporal spectra of atmospherically induced phase difference fluctuations, an analysis of an angle-of-arrival apparatus used at RADC and a study of the Fourier transform image restoration procedure.]

573. A. Consortini, "Atmospheric Propagation," Proc. of Course on Lasers & Their Applications, 31 May - 13 June 1970, Erice, Italy. [The problem of fluctuations of wave parameters experienced by a laser beam propagating through the turbulent atmosphere is discussed.]

574. A. Consortini, "Measurements of Angle of Arrival Fluctuations of a Laser Beam Due to Turbulence," AGARD Conf. Proc. No. 183, 1976. [From these measurements the structure functions of the angles of arrival are derived.]

575. A. Consortini, L. Ronchi, A. M. Scheggi and G. Toraldo di Francia, Radio Sci. J. Res., Vol. 1, p. 523, 1966. [Estimates of turbulence effects on light beams.]

576. A. Consortini, et al., "Investigation of Atmospheric Turbulence By Narrow Laser Beams," Appl. Opt., Vol. 9, No. 11, pp. 2543-2547, November 1970. [Dancing of two parallel narrow laser beams propagating through a turbulent atmosphere has been investigated theoretically and experimentally. He-Ne laser on a 130 m path, one meter from the ground.]

577. A. Consortini and L. Ronchi, "Laser Propagation Through Atmospheric Turbulence," Alta Freq., Vol. 43, No. 10, p. 769, October 1974. [Investigating the deterioration of the properties of the laser beam after propagation and deriving information about turbulence.]

578. G. F. Cudahy, An Investigation of the Degradation of a Laser Beam by High Intensity Turbulence, Doctoral Dissertation, AF Inst. of WPAFB Ohio School of Eng., Rept. No. DS/AE/76-1, 26 May 1976 (AD-A025 658/6ST). [Intensity reduction of the far field central spot formed by a collimated laser beam traversing intense turbulence was correlated with the statistical behavior of the refractive index perturbations.]

579. W. F. Dabberdt, An Investigation of Atmospheric Effects on Laser Propagation and the Impact on Eye Safety, Final Rept. June 1971 - October 1972, Stanford Res. Inst., Menlo Pk, CA (AD 755 405). [Results are presented from an experimental study of laser beam scintillation along a slant path in the atmospheric planetary boundary layer.]

580. W. F. Dabberdt, "Slant Path Scintillation in the Planetary Boundary Layer," 1972 Annual Meeting of OSA, 17-20 October 1972, San Francisco, CA. [Experimental study to determine the influence on eye safety of atmospheric thermal turbulence in causing locally high intensities of energy in laser beams. Two 15-mw He-Ne laser beams propagating along reciprocal slant paths were measured simultaneously for a path elevation of 460 m and horizontal ranges from 0.6 to 10 km, during both daytime and nighttime periods.]

*581. W. F. Dabberdt and W. B. Johnson, Atmospheric Effects Upon Laser Eye Safety, Pt II, Stanford Res. Inst., Menlo Pk, CA, 1971.

582. W. F. Dabberdt and W. B. Johnson, "Analysis of Multiwavelength Observations of Optical Scintillation," Appl. Opt., Vol. 12, No. 7, p. 1544, July 1973. [Effects of wavelength, range and thermal turbulence intensity on the laser scintillation magnitude measured over a near-ground horizontal path; 0.4880 μm, 0.6328 μm, and 1.064 μm.]

583. I. Dagkesamanskaya and V. Shishov, "Strong Intensity Fluctuations During Wave Propagation in a Statistically Homogeneous and Isotropic Media," Radiophys. Quant. Electron., Vol. 13, pp. 9-12, January 1970. [Numerical solution for the fourth moment.]

584. F. Davidson and A. Gonzalez-del-Valle, "Measurements of Three-Parameter-Log-Normally Distributed Optical Field Irradiance Fluctuations in a Turbulent Medium," JOSA, Vol. 65, No. 6, pp. 655-663, June 1975. [Probability distribution functions for scintillations measured in water (to simulate air turbulence) was truncated three parameter log normal.]

585. K. L. Davidson and T. M. Houlihan, "Turbulence Effects Upon Laser Propagation in the Marine Boundary Layer," SPIE, Vol. 75, 22-23 22-23 March 1976, Reston, VA. [Shipboard measurements of small scale temperature and velocity fluctuations have been accomplished to determine optical wave propagation properties of the marine boundary layer. Measurements were recorded for ocean conditions in Monterey Bay and in the confines of the Pacific Missile Range.]

586. J. I. Davis, "Consideration of Atmospheric Turbulence in Laser System Design," Appl. Opt., Vol. 5, pp. 139-147, January 1966. [General discussion of beam steering and spreading, image dancing and blurring, scintillation and phase fluctuations.]

587. P. H. Deitz, "Optical Method for Analysis of Atmospheric Effects on Laser Beams," Symp. on Modern Optics, Polytech. Inst. of Brooklyn, NY, 22-24 March 1967, pp. 757-774. [The power density spectrum is derived from intensity profiles and compared to the spectral densities predicted by Tatarski and to those measured by previous techniques.]

588. P. H. Deitz, Optical Propagation in a Near Earth Environment, Rept. No. BRL-TN-1708, Ballistic Res. Labs., Aberdeen Proving Ground, MD, Proc. of Meeting of Panel on Remote Atmospheric Probing, Natl. Acad. of Sci., Chicago, IL, 18 April 1968 (AD 681 905). [Describes optical measurements of the magnitude of scintillation as a function of the range and refractive index structure coefficient. The results are compared with the Tatarski and deWolf geometrical optics saturation equations.]

589. P. H. Deitz and N. J. Wright, Saturation of Scintillation Magnitude in Near-Earth Optical Propagation, Ballistic Res. Labs., Aberdeen Proving Ground, MD, Rept. No. BRL-MR-1941-Rev., October 1968 (AD 681 352). [Both a pulsed laser and a He-Ne laser have been used as optical sources to examine the magnitude of scintillation as a function of range and strength of turbulence over a near-earth, horizontal path. Verified existence of saturation.]

590. P. H. Deitz and N. J. Wright, "Saturation of Scintillation Magnitude in Near-Earth Optical Propagation," JOSA, Vol. 59, No. 5, pp. 527-535, May 1969. [Photo-optical measurements indicate that the variance increases for ranges up to about 700 m, at which distance saturation occurs.]

591. D. A. deWolf, "Wave Propagation Through Quasi-Optical Irregularities," JOSA, Vol. 55, pp. 812-817, July 1965.

592. D. A. deWolf, "Saturation of Irradiance Fluctuations Due to Turbulent Atmosphere," JOSA, Vol. 58, pp. 461-466, April 1968. [Predicts a Rayleigh distribution.]

593. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation, Quarterly Progress Rept. No. 2, 9 September - 8 December 1971, Rept. No. PRRL-71-CR-44, RCA Labs, Princeton, NJ, RADC-TR-72-32, January 1972 (AD 737 838).

594. D. A. deWolf, Strong Amplitude Fluctuations of Wave Fields Propagating through Turbulent Media, Rept. No. PRRL-72-CR-11, RCA Labs, Princeton, NJ, February 1972 (AD 740 632). [Presents an exhaustive survey, correction, and expansion of the results that can be obtained through selective summation of averaged products of Born-series.]

595. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation, Quarterly Progress Rept. No. 3, 9 December 1971 - 8 March 1972, Rept No. PRRL-72-CR-12, RCA Labs, Princeton, NJ, April 1972 (AD 744 099).

596. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation, Quarterly Technical Rept. No. 1, 19 June - 18 September 1972, Rept. No. PRRL-72-CR-45, RCA Labs, Princeton, NJ (AD 753 401). [Some remarks are presented on Furutsu's recent theoretical analysis of irradiance scintillation and the author defines and computes useful criteria for the resolution of point features on an illuminated target in turbulent air. The results are related to the work on focal-spot areas.]

597. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation, Quarterly Techical Rept. No. 2, 19 September 1972 - 15 December 1972, Rept. No. PRRL-73-TR-1, RCA Labs, Princeton, NJ (AD 757 221). [Reports results on Furutsu's contested theory of beam wave irradiance in turbulent air.]

598. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation, Summary Rept. June 1972 - March 1973, Rept. No. PRRL-73-CR-28, RCA Labs, Princeton, NJ, April 1973 (AD 763 109). [It appears important to make a distinction between focused and other beams. Amplitude scintillations appear to be unimportant in the former. Angle-of-arrival power spectra have been computed for a simple interferometer and these also contain the temporal information of focal-spot fluctuations.]

599. D. A. deWolf, Effects of Turbulence Instabilities on Laser Propagation (Phase II), Final Rept. April 1973 - 15 August 1973, Rept. No. PRRL-73-CR-47, RCA Labs, Princeton, NJ (AD 766 137/4). [It is shown that amplitude scintillation is unimportant in focused beams and is dominant in collimated and diverging beams.]

600. D. A. deWolf, "Strong Irradiance Fluctuations in Turbulent Air, I, Plane Waves," JOSA, Vol. 63, No. 2, pp. 171-179, February 1973. [Analytical results are found for irradiance statistics of a plane wave propagating through uniformly turbulent air.]

601. D. A. deWolf, "Strong Irradiance Fluctuations in Turbulent Air, II, Spherical Waves," JOSA, Vol. 63, No. 10, pp. 1249-1253, October 1973. [Extension of previous work. Main result is a saturation-regime asymptote for the log-amplitude variance $<\delta x^2>$. Comparisons with recent data are made.]

602. D. A. deWolf, "Strong Irradiance Fluctuations in Turbulent Air, III, Diffraction Cut-Off," JOSA, Vol. 64, No. 3, pp. 360-365, March 1974. [Theory is developed further to account for a saturation of the variance in the case where the Fresnel radius $(L/k)^{\frac{1}{2}}$ exceeds the microscale ℓ_o.]

603. D. A. deWolf, "Waves in Turbulent Air, A Phenomenological Model," Proc. IEEE, Vol. 62, pp. 1523-1529, November 1974. [Strong scintillation theory, presents physical model for saturation. Shows that statistics for index of refraction structure constant are gaussian since field consists of independent contributions of many off-axis eddies.]

604. D. A. deWolf, "Coherence of a Light Beam Through an Optically Dense Turbid Layer (Atmospheric Optics)," Appl. Opt., Vol. 17, No. 8, p. 1280, 15 April 1978. [Considers a plane wavefront normally incident upon a cloud and the coherence measured at two locations on the ground. The mutual coherence function at the detectors is derived.]

605. D. A. deWolf, "Waves in Random Media: Weak Scattering Reconsidered," JOSA, Vol. 68, No. 4, pp. 475-479, April 1978. [Theoretical treatment considering more terms than the "Rytov approximation."]

606. L. Dolin, "Propagation of a Narrow Light Beam in a Random Medium," Radiofiz., Vol. 7, pp. 380-391 (in Russian), May 1964. [Applies transport methods.]

607. J. A. Dowling, J. A. Curcio and H. Shenker, "Experimental Studies of Focused Laser Beams Propagating Through Near-Earth Atmospheric Turbulence," Prog. of 1971 Spring Meeting of OSA, 5-8 April 1971, Tucson, AZ. [Focal-spot diameter and beam wander have been studied at ranges up to 2 km. Results are compared with existing theory.]

608. J. A. Dowling, J. A. Curcio and H. Shenker, "Propagation of Focused Laser Beams Through Atmospheric Turbulence," Dig. of Tech. Papers of 1971 IEEE/OSA Conf., 2-4 June 1971, Washington, D.C. [Laser beams of 633 nm and 10.6 μm wavelengths over level grassy terrain at a height of 8 ft. The transmitting telescope was focused on a scanning receiver system for ranges up to 2 km.]

*609. J. A. Dowling and P. M. Livingston, "Behavior of Focused Beams in Atmospheric Turbulence - Measurements and Comments on Theory," JOSA, Vol. 63, No. 7, pp. 846-858, July 1973. [Laser beam propagation through atmospheric turbulence is analyzed theoretically and compared with measurements at 0.63 and 10.6 μm. Measurements on beam spread do not agree with theory because exposure times exceeded L_o/V.]

610. D. D. Duncan, Theoretical Study of the Turbulence Induced Scintillation of a Dirty Laser Beam, Interim Rept. January 1977 - September 1977, Rept. No. RADC-TR-77-430 (AD-A050 874/7ST). [Use is made of the extended Huygens-Fresnel principle in deriving a very general but compact mathematical expression for the temporal scintillation spectrum of an unspecified source field with an arbitrary shaped extended receiver aperture. Restricted to the weak turbulence regime.]

611. J. R. Dunphy and J. R. Kerr, "Scintillation Measurements for Large Integrated Path Turbulence," JOSA, Vol. 63, pp. 981-986, 1973. [Observed rapid dropoff in log-amplitude covariance function in strong turbulence. Measured frequency spectrum in weak and strong turbulence.]

612. J. R. Dunphy and J. R. Kerr, "Turbulence Effects on Target Illumination by Laser Sources: Unified Analysis and Experimental Verification," NATO/AGARD Conf. on Optical Propagation in the Atmosphere, Lyngby, Denmark, Paper 21, 27-31 October 1975. [Shows unity limit of saturation.]

*613. J. R. Dunphy and J. R. Kerr, "Turbulence Effects on Target Illumination by Laser Sources: Phenomenological Analysis and Experimental Results," Appl. Opt., Vol. 16, No. 5, pp. 1345-1358, May 1977. [Simple engineering model for mean and variance as function of transmitter size and focus, wavelength, pathlength, and turbulence strength (including saturation). Error in key expression (Gebhardt-Breaux). Comparison with theory.]

614. N. N. D'Yachenko, V. Ya. S'Edin and S. S. Khmelevtsov, "Fluctuations of Intensity of Focused Laser Beams During Propagation in a Turbulent Atmosphere," Izv. vuz. Fiz., No. [illegible] p. 132, 1974, Trans. in Sov. Phys. J. [Experiments are described on the measurements of intensity fluctuations in a focused laser beam (λ = 0.63 μm) over path lengths of 1.2 and 3.5 km. The results are used to calculate correlation functions and the distribution of intensity fluctuations.]

615. W. R. Edmonds, "Isoline Approach to Portraying Atmospheric Turbulence Induced Laser Beam Spread," Appl. Opt., Vol. 16, No. 6, p. 1606, June 1977. [Considers effects of turbulence on a laser beam from an airborne source and focused [illegible] receiver at any altitude at almost any zenith angle.]

616. R. L. Fante, Propagation of Electromagnetic Waves Through Turbulent Media Using Transport Theory, AFCRL-72-0733, 18 December 1972 (AD 757 491). [Transport methods have been employed to study the propagation of a narrow-angle electromagnetic beam through a turbulent medium. Results are presented for the mean-square angular divergence of the beam, cross section of the beam, and the power received by a planar aperture in the medium.]

617. R. L. Fante, Mutual Coherence Function of a Beam Propagating in a Turbulent Medium, AFCRL-TR-73-0566, 7 September 1973 (AD 772 659/9). [Using transport theory the mutual coherence function of a beam propagating in a turbulent medium has been studied in detail, including the effect of the beam size, focal length and strength of the turbulence.]

618. R. L. Fante, Mutual Coherence Function and Frequency Spectrum of a Laser Beam Propagating Through Atmospheric Turbulence, AFCRL-TR-74-0079, 6 February 1974 (AD 781 039/3). [The mutual coherence function of a laser beam propagating in turbulence with a modified von Karman spectrum for the index of refraction fluctuations, including a parametric study of the effect on the MCF of varying beam size, focal length, and the properties of the turbulence was computed.]

619. R. L. Fante, Frequency Spectrum of Optical Waves Propagating in a Moving Turbulent Atmosphere, AFCRL-TR-0135, 8 March 1974 (AD 780 623/5).

620. R. L. Fante, "Mutual Coherence Function and Frequency Spectrum of a Laser Beam Propagating Through Atmospheric Turbulence," JOSA, Vol. 64, No. 5, pp. 592-598, May 1974. [A solution for beam spreading is derived. Dependence of MCF on beam diameter, focal length and degree of turbulence are analyzed.]

621. R. L. Fante, Intensity, Coherence, and Frequency Spectrum of a Focused Beam in a Random Medium, AFCRL-TR-74-0335, 26 July 1974 (AD 787 651/9SL). [Numerical results have been obtained for the effect of the strength of turbulence on the intensity, mutual coherence function, and frequency spectrum of a focused beam propagating in a random medium having a von Karman spectrum for the index of refraction fluctuations.]

622. R. L. Fante, "Intensity of a Focused Beam in a Turbulent Medium," Proc. of IEEE, Vol. 62, No. 10, pp. 1400-1402, October 1974 (AD-A012 180/6ST). [The effect of the strength of turbulence on the intensity distribution in the focal plane of a focused laser beam is studied.]

623. R. L. Fante, Covariance of the Intensity Fluctuations of a Wave in a Random Medium, AFCRL-TR-74-0478, 27 September 1974 (AD-A003 384/5ST).

624. R. L. Fante, "Numerical Evaluation of the Mutual Coherence Function of a Laser Beam in Atmosphere Turbulence," Proc. of IEEE, Vol. 62, No. 11, pp. 1604-1606, November 1974 (AD-A004 281/2ST). [With a modified von Karman spectrum for the index of refraction fluctuations, a parametric study was performed of the effect of varying beam size, focal length, and the properties of the turbulence.]

625. R. L. Fante, Irradiance Scintillations: Comparison of Theory with Experiment, AFCRL-TR-74-0626, 20 December 1974 (AD-A006 365/1ST). [Calculations are made using a new theory for the covariance of the irradiance scintillations of an optical wave in a strong turbulent medium. These are compared with recent experimental data and found to be in good agreement.]

626. R. L. Fante, "Electric Field Spectrum and Intensity Covariance of a Wave in a Random Medium," Radio Sci., Vol. 10, pp. 77-85, January 1975. [Physical analytical model for strong turbulence that does not rely on experimentally determined parameters (like others do).]

*627. R. L. Fante, Propagation in Turbulent Media: A Review of Recent Progress, AFCRL-TR-75-0105, 24 February 1975 (AD-A010 413/3ST). [Reviewed the recent developments on beam propagation in a turbulent medium. These include the effect of the turbulence on beam intensity, spread, coherence, wander, angle of arrival, scintillation and distortion, as well as other related topics.]

628. R. L. Fante, "Some New Results on Propagation of Electromagnetic Waves in Strongly Turbulent Media," IEEE Trans. Antennas Propag., Vol. AP-23, pp. 689-695, May 1975 (AD-A003 642/6ST). [Presents new results for the covariance of the intensity fluctuations of a plane wave propagating in a strongly turbulent medium, and evaluates the consequences of these new results on aperture averaging, angle of arrival fluctuations, and the temporal frequency spectrum of the intensity scintillations. Derives phase structure function for strong turbulence region.]

629. R. L. Fante, "Some Results for the Variance of the Irradiance of a Finite Beam in a Random Medium," JOSA, Vol. 65, No. 5, pp. 608-610, May 1975. [Shows theoretically that if turbulence is sufficiently strong the properties of the variance is independent of initial beam structure as has been observed.]

630. R. L. Fante, Optical Beam Propagation in Turbulent Media, AFCRL-TR-75-0439, 13 August 1975 (AD-A018 061/2ST).

631. R. L. Fante, "Electromagnetic Beam Propagation in Turbulent Media," Proc. of IEEE, Vol. 63, No. 12, pp. 1669-1692, December 1975 (AD-A020 778/7ST). [The most recent developments on the propagation of optical beams in a turbulent medium, such as the clear atmosphere, are reviewed. Among the phenomena considered are beam spreading, beam wander, loss of coherence, scintillations, angle-of-arrival variations, and short-pulse effects.]

632. R. L. Fante, "Two Source Spherical Wave Structure Function in Atmospheric Turbulence," JOSA, Vol. 66, No. 1, p. 74, January 1976. [Evaluated the functions for the case of weak turbulence governed by the Kolmogorov spectrum.]

633. R. L. Fante, "Optical Propagation Through Strong Turbulence," SPIE Vol. 142 Optical Properties of the Atmosphere, p. 104, 1978. [In this paper, how and why turbulence distorts the irradiance distribution and coherence properties of a light beam are discussed with special emphasis on the irradiance scintillations in strong turbulence.]

634. R. L. Fante and J. L. Poirier, "Mutual Coherence Function of a Finite Optical Beam in a Turbulent Medium," Appl. Opt., Vol. 12, No. 10, p. 2247, October 1973 (AD 772 276/2). [It is demonstrated that the Markov appoximation, transport theory, the Huygens-Fresnel principle, and the Bethe-Salpeter equation all lead to identical results for the mutual coherence function of an optical beam in a turbulent medium.]

635. R. L. Fante and R. L. Taylor, Short Term Spot Size and Beam Wander in a Turbulent Medium, AFCRL-TR-74-0595, 27 November 1974 (AD-A006 032/7ST). [Calculated results have been used to calculate the probability that, due to beam wander, the beam will fail to hit a receiver aperture.]

636. Z. Feizulin and Y. Kravtsov, "Broadening of a Laser Beam in a Turbulent Medium," Radiophys. Quant. Electron., Vol. 10, pp. 33-35, January 1967. [Theoretical study of the broadening accounting for non-uniformities in medium, diffraction broadening and beam wander.]

637. A. S. Fields, Optical Phase and Intensity Fluctuations in a Refractive Index Microstructure: A Mathematical Analysis, Rept. No. NSRDC-6-196, Naval Ship R&D Center, Annapolis, MD, July 1972 (AD 746 120). [Studies have been published which extend and apply the Kolmogorov theory of turbulence to the fluctuations of optical refractive index in the ocean due to salinity and temperature microstructure.]

638. M. W. Fitzmaurice, Experimental Investigations of Optical Propagation in Atmospheric Turbulence, NASA-TR-R-370, August 1971 (N71-33222).

639. M. W. Fitzmaurice and J. L. Bufton, "Measurement of Log-Amplitude Variance," JOSA, Vol. 59, No. 4, pp. 462-463, April 1969. [Shows that the saturation effect is linear with skewness of the log amplitude.]

640. D. L. Fried, "Statistics of a Geometric Representation of Wavefront Distortion," JOSA, Vol. 55, pp. 1427-1435, November 1965. [Derives relationships between phase structure function and statistics of shape of distorted wavefront. Most important distortion due to tilting of plane wavefront.]

641. D. L. Fried, "Optical Resolution Through a Randomly Inhomogeneous Medium for Very Long and Very Short Exposures," JOSA, Vol. 56, No. 10, pp. 1372-1379, October 1966. [Theoretical study of effect of turbulence on optical resolution. Develops equation for short term irradiance statistics using Huygens-Fresnel principle.]

642. D. L. Fried, "Aperture Averaging of Scintillation," JOSA, Vol. 57, No. 2, pp. 169-175, February 1967. [Relationship between the statistics of log-amplitude fluctuations and irradiance fluctuations due to atmospheric turbulence is derived. This is used to evaluate the effect of use of a large aperture diameter in reducing the variance of a fluctuating signal.]

*643. D. L. Fried, "Propagation of a Spherical Wave in a Turbulent Medium," JOSA, Vol. 57, No. 2, pp. 175-180, February 1967. [The log-amplitude covariance and the phase-structure function, associated with the statistics of propagation of a spherical wave in a turbulent medium, are derived for a propagation path over which the statistics of turbulence are constant. Analytic and graphical representation of the results are presented.]

644. D. L. Fried, "Atmospheric Modulation Noise in an Optical Heterodyne Receiver," J. Quant. Electron., Vol. QE-3, pp. 213-221, June 1967.

645. D. L. Fried, Computer Simulation of Turbulence Induced Pointing Jitter for a Laser Designator, Rept. No. DRDMI-TE-CR-77-2, Army Missile R&D Command, Restone Arsenal, AL, Advanced Sensors Directorate, March 1976 (AD-A039 486/6ST). [Statistics of turbulence-induced, angle-of-arrival fluctuations are formulated and presented in a form suitable for computer calculations of the fluctuation power spectrum for the baseline propagation case of an aperture viewing a point source.]

646. D. L. Fried and G. E. Mevers, "Atmospheric Optical Effects - Polarization Fluctuation," JOSA, Vol. 55, p. 740L, 1965. [Polarization fluctuations in ground layer at distances from 1 to 30 km. Intensity fluctuations approximately normal.]

647. D. L. Fried and J. B. Seidman, "Laser-Beam Scintillation in the Atmosphere," JOSA, Vol. 57, No. 2, pp. 181-185, February 1967. [The variance of the log-amplitude of a laser beam is evaluated for a horizontal propagation path through the atmosphere.]

648. D. L. Fried, G. E. Mevers and M. P. Keister, "Measurements of Laser Beam Scintillation in the Atmosphere," JOSA, Vol. 57, No. 6, pp. 787-797, June 1967. [Detailed studies of intensity fluctuations of a 0.63 μm gas laser, indicated log-normal distribution regardless of collecting aperture.]

649. D. L. Fried and R. A. Schmeltzer, "Effects of Atmospheric Scintillation on an Optical Data Channel - Laser Radar and Binary Communications," Appl. Opt., Vol. 6, No. 10, pp. 1729-1737, October 1967. [Effects of scintillation on an optical data channel are analyzed and numerical results presented. Scintillation with a log normal distribution typical of atmospheric optical effects is assumed. Analysis is concerned with the target miss probability of a laser radar and the bit error probability of an optical binary communications link.]

650. Y. Furuhama and M. Fukushima, "Measurement of Log-Irradiance Fluctuation of He-Ne Laser in the Atmosphere," J. Radio Res. Lab., Vol. 19, No. 100, p. 197, 1972. [The cumulative probability distributions of log-irradiance show excellent agreement with Rice-Nakagami distribution in the region of weak fluctuations.]

651. Y. Furuhama and M. Fukushima, "Measurements of the Log-Irradiance Distribution of a Laser Wave Propagated Through the Turbulent Atmosphere," Boundary-Layer Meteorol., Vol. 4, No. 1-4, p. 433, April 1973. [Log-irradiance fluctuations of He-Ne laser light were simultaneously measured at 3 different points in the receiving plane. Excellent agreement with the Rice-Nakagami distribution in the region of weak fluctuations.]

652. Y. Furuhama, et al., "Propagation Characteristics of Laser Waves Through the Turbulent Atmosphere - Cumulative Probability Distribution," Electron. & Commun., Vol. 56, No. 4, p. 50, April 1973. [The validity of Furutsu's theory for a weak scintillation region has been confirmed by the simultaneous measurement of the logarithmic irradiance of scintillation.]

653. K. Furutsu, "On the Statistical Theory of Electromagnetic Waves in a Fluctuating Medium," J. Res., Nat. Bur. Stnd., Vol. 67D, pp. 303-310, March 1963.

654. K. Furutsu, "Statistical Theory of Wave Propagation in a Random Medium and the Irradiance Distribution Functions," JOSA, Vol. 62, No. 2, pp. 240-254, February 1972. [The complete statistical description of the waves in a random medium can be obtained from the characteristic functional or the cumulant functional of the wave function. The basic equations of these functionals are found first for the gaussian medium and then for the nongaussian medium.]

655. C. S. Gardner and M. A. Plonus, "The Effects of Atmospheric Turbulence on the Propagation of Pulsed Laser Beams," Radio Sci., Vol. 10, No. 1, p. 129, January 1975. [Using the Rytov theory, general expressions for the pulse fluctuations are derived in terms of arbitrary beam geometries and pulse shapes.]

656. S. S. Gasparyan, R. A. Kazaryan and R. G. Manucharyan, "Experimental Investigation of Fluctuations of the Laser Radiation Intensity in the Atmosphere," Sov. J. Quant. Electron., Vol. 3, No. 4, p. 355, Jan-Feb 1974. [Experimental observations are reported for a 25 km path, at heights above ground level varying between 20-500 m along its length.]

657. F. G. Gebhardt and S. A. Collins, Jr., "Log-Amplitude Mean for Laser Beam Propagation in the Atmosphere," JOSA, Vol. 59, No. 9, pp. 1139-1148, September 1969. [An integral expression is evaluated for the log-amplitude mean value of a guassian or laser-like optical beam in a turbulent atmosphere.]

658. E. Gel'fer, et al., "Measurement of the Light Intensity on the Axis at the Center of Gravity of a Focused Light Beam," Radiophys. Quant. Electron., Vol. 15, pp. 696-699, June 1972. [Beam spread agrees with theory.]

659. E. Gel'fer, et al., "Correlation of the Shift of the Center of Gravity of a Focused Light Beam in a Turbulent Medium," Radiophys. Quant. Electron., Vol. 16, pp. 182-187, February 1973. [Measured over a 1 km horizontal path 2.5 m above the ground with photographic films; compares well with theory.]

660. K. H. George and W. E. Webb, Study of Atmospheric Effects on Laser Communications Systems, Vol. 2 - Atmospheric Effects on Wave Propagation at 10.6 Microns, Interim Rept., NASA-CR-103113, March 1971 (N71-26419).

661. T. J. Gilmartin, The Propagation of a Laser Beam in a Turbulent Atmosphere Whose Refractive Index Fluctuations are Gaussian Correlated, Purdue Univ., 1968, Avail. from Univ. Microfilms, Ann Arbor, MI.

662. T. J. Gilmartin, "10.6 μm Laser Radar Propagation Experiments," Proc. 4th Laser Conf., Vol. II, pp. 1543-1555, January 1970. [Measured clear atmosphere transmission, optical turbulence at ground level and resulting beam spread.]

663. T. J. Gilmartin and J. Z. Holst, "Atmospheric Optical Coherence Measurements at 10.6 and 0.63 μm," 1972 Annual Meeting of OSA, 17-20 October 1972, San Francisco, CA. [Simultaneous measurements of the atmospheric spatial coherence have been made with 10.6 and 0.63 μm laser radiation, and with white light.]

664. K. S. Gochelashvily, "Saturation of the Fluctuations of Focused Radiation in a Turbulent Medium," Radiophys. Quant. Electron., Vol. 14, pp. 470-473, April 1971. [Computes phase structure function in linear region using Rytov method.]

665. K. S. Gochelashvily, "Focused Laser Irradiance Fluctuations in a Turbulent Medium," Opt. Acta, Vol. 20, No. 3, p. 193, March 1973. [It is shown that the spectral and correlation properties of the random field of intensity depend in an essential manner upon the magnitude of the phase structure function.]

666. K. S. Gochelashvily, "Propagation of Focused Laser Radiation in a Turbulent Medium," Sov. J. Quant. Electron., Vol. 4, No. 4, p. 465, October 1974. [The correlation theory of fluctuations in the intensity of focused radiation in a turbulent medium is extended to allow the attainment of saturation of the fluctuations at increasing propagation distances.]

667. K. S. Gochelashvily and V. I. Shishov, "Laser Beam Scintillation Beyond a Turbulent Layer," Opt. Acta, Vol. 18, p. 313, April 1971. [Analytical expression is derived for covariance of irradiance in Fresnel zone for strong and weak turbulence.]

668. K. S. Gochelashvily and V. I. Shishov, "Focused Irradiance Fluctuations Beyond a Layer of Turbulent Atmosphere," Opt. Acta, Vol. 19, p. 327, April 1972. [Theoretical treatment of spectral and correlation properties of fluctuations, including saturation, using phase-screen approximation.]

669. K. S. Gochelashvily and V. I. Shishov, "Saturated Fluctuations of Laser Radiation Intensity in a Turbulent Medium," Zh. Eksp. & Teor. Fiz., Vol. 66, No. 4, p. 1237, April 1974, Trans. in Sov. Phys. JETP. [An asymptotic theory is developed of saturated fluctuations of the intensity of quasimonochromatic radiation propagating over large distances in a turbulent medium with a power-law spectrum of refractive index fluctuation.]

670. K. S. Gochelashvily, V. G. Pevgov and V. I. Shishov, "Saturation of Fluctuations of the Intensity of a Laser Radiation at Large Distances in a Turbulent Atmosphere (Fraunhofer Zone of Transmitter)," Sov. J. Quant. Electron., Vol. 4, No. 5, p. 632, November 1974. [The analysis is based on a solution of the equation for the fourth order coherence function for initially spherical waves. A description is obtained of the mode of saturation of the relative fluctuation intensities which is in good agreement with experimental measurements.]

671. K. S. Gochelashvily and V. I. Shishov, "Saturation of Laser Irradiance Fluctuations Beyond a Turbulence Layer," Opt. & Quant. Electron., Vol. 7, No. 6, p. 524, November 1975. [An asymptotic theory of saturated fluctuations of laser irradiance diffracted by a thin layer of turbulent medium is built.]

672. K. S. Gochelashvily and V. I. Shishov, "Strong Intensity Fluctuations of Laser Radiation in a Turbulent Atmosphere, The Distribution Function," Zh. Eksp. & Teor. Fiz., Vol. 74, No. 6, p. 1974, June 1978, Trans. in Sov. Phys. JETP. [A method is proposed for calculation on the distribution function of intensity fluctuations in a medium with Kolmogorov turbulence in the region of saturated flicker.]

673. I. Goldstein, et al., "Heterodyne Measurements of Light Propagation Through Atmospheric Turbulence," Proc. IEEE, Vol. 53, pp. 1172-1180, September 1965. [Phase perturbation measured at 0.6328 and 1.15 μm in horizontal paths (4 and 23.8 km) consistent with theory.]

674. N. Ts. Gomboev, et al., "Spatial Correlation of Strong Intensity Fluctuations in a Narrow Laser Beam Travelling in the Atmophere," Sov. J. Quant. Electron., Vol. 5, No. 6, p. 684. [The spatial correlation function was measured of strong intensity fluctuations in a narrow gaussian beam from a He-Ne laser transmitted over an inclined atmospheric path. Results obtained by two methods agreed with calculations based on the Huygens-Kirchhoff method and differed from uncollimated beam results.]

675. F. E. Goodwin, "Laser Propagation in the Terrestrial Atmosphere," Proc. 1st Laser Conf., Vol. II, pp. 13-25, January 1964. [Measured beam width (3 db) vs. path length and condition. Method of Tatarski not applicable to laser turbulence effects.]

676. M. E. Gracheva, "Investigation of the Statistical Properties of Strong Fluctuations in the Intensity of Light Propagated Through the Atmosphere Near the Earth," Radiophys. Quant. Electron., Vol. 10, pp. 424-433, 1967. [Verified existence of saturation of scintillation of optical beams using mercury lamp over paths of 250, 50, 1000 and 1750 m.]

677. M. E. Gracheva and A. S. Gurvich, "Strong Fluctuations in the Intensity of Light Propagated Through the Atmosphere Close to the Earth," Radiophys. Quant. Electron., Vol. 8, p. 511, 1965. [Data on fluctuation of signal in the atmosphere. First measurement of saturation for $k^{7/6} L^{11/16} C_n^2 > 1$.]

*678. M. E. Gracheva, A. S. Gurvich and M. A. Kallistratova, "Dispersion of Strong Atmospheric Fluctuations in the Intensity of Laser Radiation," Radiophys. & Quant. Electron., Vol. 13, pp. 40-42, 1970. [First found irradiance fluctuations saturated for very strong turbulence. Rytov expression invalid for $\sigma_I^2 > 0.3$. Measured super-saturation.]

679. M. E. Gracheva, et al., "Distribution of Probabilities of Strong Light Intensity Fluctuations in the Atmosphere (Laser Beam)," Izv. vuz. Radiofiz., Vol. 17, No. 1, p. 105, 1974, Trans. in Radiophys. & Quant. Electron. [Measurements were made at daytime under the conditions of strong fluctuations of the air refractive index.]

*680. M. E. Gracheva, et al., Similarity Correlations and Their Experimental Verification in the Case of Strong Intensity Fluctuations of Laser Radiation, Translation LRG-73-T-28, Aerospace Corp. Lib. Serv., POB 92957, Los Angeles, CA 90009, 1974. [Measures frequency spectrum in weak and strong turbulence. Nearly log-normal for $\sigma_I^2 < 0.3$ and $25 < \sigma_I^2 < 100$.]

681. V. Granatstein, "Multiple Scatter of Laser Light from a Turbid Medium," Appl. Opt., Vol. 11, p. 1217, May 1972.

682. A. S. Gurvich, Light Intensity Fluctuations in Diverging Beams, Rept. No. FTD-HT-23-1863-72, Foreign Tech. Div., WPAFB, OH, 5 February 1973, Edited trans. of Izv. Vysshikh Uchebnykh Zavednii Radiofiz (USSR), Vol. 12, No. 1, p. 147, 1969 by V. Mesenzeff (AD 756 094). [Presents a calculation of the dispersion of the light intensity logarithm along the axis of a laser beam propagating in the atmosphere. General formulas, derived by Schmeltzer (1967) by a smooth perturbation technique to describe the propagation of a bounded monochromatic light beam, are used in the calculations.]

683. A. S. Gurvich and M. A. Kallistratova, Radiofiz., Vol. 11, p. 66, 1968. [Measured angle of arrival variance and behavior of structure phase function versus path and turbulence intensity.]

684. A. S. Gurvich, et al., "Fluctuation in the Parameters of a Light Wave From a Laser During Propagation in the Atmosphere," Radiophys. Quant. Electron., Vol. 11, p. 771, September 1968. [Measured angle of arrival spectrum and verified saturation phenomena.]

685. A. S. Gurvich and V. V. Pokasov, "Spectrum of Fluctuations of Laser Radiation in a Turbulent Atmosphere," Atm. & Oceanic Phys., Vol. 8, No. 8, p. 878, August 1972. [Measurements of the frequency spectra of light intensity fluctuations in a direct laser beam of wavelength 0.63 μm, traversing a 1750 m path through weak drizzle.]

686. A. S. Gurvich and V. I. Tatarski, "Statistics of Photoreadings of Light Propagation in the Turbulent Medium," Izv. vuz. Radiofiz., Vol. 16, No. 3, p. 434, 1973, Trans. in Radiophys. & Quant. Electron., Vol. 16, No. 3. [Synchronous measurements are made of the relative dispersion of light intensity fluctuations and of photocounts of light propagating in the turbulent atmosphere along the path of 2650 m. The source of light is He-Ne laser.]

687. A. S. Gurvich and V. V. Pokasov, Frequency Spectra of Strong Fluctuations of Laser Emission in a Turbulent Atmosphere, Rept. No. FTD-HT-23-585-74, Foreign Tech. Div, WPAFB, OH, 28 November 1973, Edited trans. of Izv. vuz. Radiofiz., Vol. 16, No. 6, p. 913, 1973 by V. Mesenzeff (AD 771 693/9). [Results of an experimental study done on frequency fluctuation spectra of laser emission in an atmosphere under conditions of strong and weak fluctuations.]

688. A. S. Gurvich and V. I. Tatarski, "Coherence and Intensity Fluctuations of Light in the Turbulent Atmosphere," Radio Sci., Vol. 10, No. 2, January 1975. [Measured frequency spectrum in weak and strong turbulence.]

689. A. S. Gurvich and S. S. Kashkarov, "Radiation Intensity Fluctuations in Laser Beams in the Atmosphere," Izv. vuz. Radiofiz., Vol. 18, No. 1, p. 69, 1975, Trans. in Radiophys. & Quant. Electron. [The experimental data on RMS values and the correlation coefficients of the intensity fluctuations of narrow laser beams on the near earth trace with length 16.3 km are given.]

690. A. S. Gurvich, et al., "Frequency Spectra of Laser Radiation Intensity Fluctuations at 0.63 and 10.6 Micron Wavelengths in the Atmosphere," Radiophys. & Quant. Electron., Izv. vuz. Radiofiz., Vol. 18, No. 4, p. 610, 1975. [The methods, findings and shortcomings of previous studies of fluctuations in laser radiation intensity at different wavelengths are outlined. The results of experimental measurements of the fluctuation spectra.]

691. B. C. Haagensen, Laser Beam Scintillation in the Marine Boundary Layer, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1973 (AD 765 676/2). [Intensity scintillation in a laser beam at 0.63 micrometers in the marine boundary layer has been studied over a 4.3 kilometer horizontal path across Monterey Bay and also from shore to ship at San Nicolas Island.]

692. J. L. Hayes and R. L. Kurtz, Experimental Measurement of Optical Angular Deviation Caused by Atmospheric Turbulence and Refraction, NASA-TN-D-3439, May 1966 (N66-25558).

693. J. Herrman and L. C. Bradley, Laser Propagation Through a Turbulent Medium, MIT Lincoln Lab Rept. No. ESD-TR-72-195, 19 December 1972.

694. H. Hidalgo and R. Vaglio-Laurin, Description of Atmospheric Turbulence of Linear Propagation of Laser Beams, Rept. No. RP-P-600, IDA, Arlington, VA, July 1970 (AD 709 434). [Considers the fluid mechanical aspects and data relevant to the propagation of low power-density lasers in the atmospheric boundary layer.]

695. W. R. Hinchman and A. L. Buck, "Fluctuations in a Laser Beam Over 9- and 90-Mile Paths," Proc. IEEE, Vol. 52, pp. 305-306, 1964. [Visual observations indicated broadening of He-Ne beam of 8 and 13 seconds of arc over distances of 15 and 145 km.]

696. T. L. Ho, "Log-Amplitude Fluctuations of Laser Beam in a Turbulent Atmosphere," JOSA, Vol. 59, No. 4, pp. 385-390, April 1969. [Rytov approximation is used to calculate log-amplitude fluctuations in linear region. No comparison with measurements.]

697. T. L. Ho, "Coherence Degradation of Gaussian Beams in a Turbulent Atmosphere," JOSA, Vol. 60, No. 5, pp. 667-673, May 1970. [Method of small perturbations is used with the Kolmogorov spectrum to calculate the degree of coherence.]

698. H. Hodara, "Laser Wave Propagation Through the Atmosphere," Proc. IEEE, Vol. 54, pp. 368-375, March 1966. [Simple expressions are obtained for the effects of beam scanning (quivering), phase change, cross section change (breathing), and polarization fluctuation.]

699. D. H. Höhn, "Effects of Atmospheric Turbulence on the Transmission of a Laser Beam at 6328 Å, I - Distribution of Intensity," Appl. Opt., Vol. 5, No. 9, p. 1427, 1966. [Investigated intensity distribution of 0.6328 μm laser at various distances. Log-normal fit 51 out of 68 measured distribution functions.]

700. D. H. Höhn, "Effects of Atmospheric Turbulence on the Transmission of a Laser Beam at 6328 Å, II - Frequency Spectra," Appl. Opt., Vol. 5, No. 9, p. 1433, 1966. [Investigated the frequency spectra of intensity fluctuations of a 0.6328 μm laser over 4.5 and 14.5 km paths.]

701. D. H. Höhn, "Depolarization of a Laser Beam at 6328 Å Due to Atmospheric Transmission," Appl. Opt., Vol. 8, No. 2, p. 367, February 1969. [These experimental values are very much higher than that predicted by theories regarding turbulence-induced depolarization.]

702. D. H. Höhn, "On Atmospheric Propagation of a Laser Beam," Optik, Vol. 30, No. 2, p. 161, 1969. [Laser beam at 6328 Å was used at ranges up to 4.5 km. In most cases the distribution function of the fluctuating intensity was log-normal.]

703. D. H. Höhn, "On the Propagation of a Laser Beam in the Atmosphere, II," Optik, Vol. 30, No. 3, p. 234, 1969. [This part deals with intensity fluctuations and the mean intensity profile.]

704. G. C. Holst, Laser Beam Divergence and Far Field Measurements, Rept. No. FA-R-2075, Frankford Arsenal, Phila., PA, May 1973 (AD 765 482/5). [Several methods are available for determining the divergence from the far field pattern. These methods are experimentally verified with a He-Ne laser.]

705. J. Honbolt, "Atmospheric Turbulence," AIAA J., Vol. 11, pp. 421-437, October 1973.

706. A. J. Huber, Measurements of the Temporal Power Spectral of a Propagated 10.6 Micron Wavefront, RADC-TR-74-44, February 1974 (AD 777 259/3). [Measurements of the temporal power spectral density of the phase coherence of an atmospherically degraded 10.6 micron wavelength laser beam.]

707. A. J. Huber and R. P. Urtz, "Experimental Phase Difference Spectra for 10.6 μ," 1972 Annual Meeting of OSA, 17-20 October 1972, San Francisco, CA. [Temporal frequency spectra were obtained as a function of detecting aperture separation, sensor orientation, C_T^2 (obtained using microthermal sensors), and wind speed and direction.]

708. A. Ishimaru, "Fluctuations of a Beam Propagating Through a Locally Homogeneous Medium," Radio Sci., Vol. 4, pp. 295-305, April 1969. [Calculates intensity scintillations and computed the phase structure function in linear region using Rytov method.]

709. A. Ishimaru, "Fluctuations of a Focused Beam Wave for Atmospheric Turbulence Probing," Proc. IEEE, Vol. 57, p. 407, April 1969. [Frequency spectrum of weak turbulence using log-amplitude fluctuations; computes phase structure function using Rytov's method.]

710. W. B. Johnson, Trans. Am. Geophys. Union, Vol. 50, p. 159, 1969. [Verified existence of saturation. Abstract only.]

711. W. B. Johnson, et al., Atmospheric Effects - Laser Safety Criteria (U), AFAL-TR-68-243, 1968 (Confidential).

*712. W. B. Johnson, et al., Atmospheric Effects Upon Laser Eye Safety, Pt. I, Stanford Res. Inst., April 1970. [Experimental results indicate possibility of saturation.]

713. M. A. Kallistratova and V. V. Pokasov, "Defocusing and Shift Fluctuations of the Displacement of a Focused Laser Beam in the Atmosphere," Radiophys. Quant. Electron., Vol. 14, pp. 940-945, August 1971. [Results of measuring the turbulent defocusing and shifts of the focused radiation beam of the gas laser (λ = 0.63 μ) on 250 and 1750 m traces near the earth under the conditions of strong amplitude fluctuations.]

714. M. A. Kallistratova, "On the Effect of the Size of Optical Systems on the Definition of Light Beams in a Turbulent Atmosphere," Radiophys. Quant. Electron., Vol. 15, pp. 545-549, April 1972. [Detailed measurements of beam intensity in turbulence agree with theory.]

715. S. S. Kashkarov and K. P. Pogosyan, "Investigation of Intensity Fluctuations of λ = 10.6 μ Laser Radiation in the Atmosphere," Sov. J. Quant. Electron., Vol. 5, No. 10, p. 1267. [The relative variance of the intensity of a 10.6 μm laser beam transmitted over either 13.5 km or 16.3 km atmospheric path was measured in various turbulence conditions. The relative variance was similar to that found previously at 0.63 μm and saturated in strong turbulence.]

716. J. R. Kerr, Multiwavelength Laser Propagation Study, II, Rept. No. 1154-8, Oregon Grad. Ctr. for Study & Res., Portland, OR, July 1970 (AD 709 458). [A comprehensive, multiwavelength laser-beam propagation facility was operated over a horizontal, 1 mile path in order to investigate the adequacy of a commonly-used atmospheric model and to establish the wavelength-depedence of scintillations.]

717. J. R. Kerr, Multiwavelength Laser Propagation Study, III, Rept. No. 1154-9, Oregon Grad. Ctr. for Study & Res., Portland, OR, September 1970 (AD 712 097). [Reviews activities in a comprehensive study of multiwavelength laser scintillations due to atmospheric turbulence.]

718. J. R. Kerr, Multiwavelength Laser Propagation Study, III, Rept. No. 1154-10, Oregon Grad. Ctr. for Study & Res., Portland, OR, December 1970 (AD 717 088). [An extensive experimental investigation of multiwavelength laser beam scintillations and atmospheric turbulence characteristics has been completed. Saturation phenomenon occurs at the same scintillation levels independent of wavelength, and significant fall off of scintillation 'beyond saturation' is observed.]

719. J. R. Kerr, "Multiwavelength Propagation Experiments, III," Prog. of 1971 Spring Meeting of OSA, 5-8 April 1971, Tucson, AZ. [An extensive experimental investigation of multiwavelength laser beam scintillations and atmospheric-turbulence characteristics has been completed.]

720. J. R. Kerr, Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Rept. No. 1174-1, Oregon Grad. Ctr. for Study & Res., Portland, OR, September 1972 (AD 752 565). [Efforts that are underway on 3 aspects of the problem: (1) multiwavelength scintillations over a long horizontal path, (2) turbulence intermittency effects, and (3) transtter-aperture effects including the calculation of atmospherically-induced beam wander.]

721. J. R. Kerr, Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Rept. No. 1174-2, Oregon Grad. Ctr. for Study & Res., Portland, OR, December 1972 (AD 757 562). [Topics are (1) multiwavelength scintillation over a long horizontal path with a very high integrated-path turbulence level; (2) finite-beam or transmitter aperture effects including beam wander, spread, and scintillation; and (3) turbulence intermittency effects.]

722. J. R. Kerr, "Comments on 'Irradiance Fluctuations in Optical Transmission Through the Atmosphere'," JOSA, Vol. 62, No. 7, p. 916, July 1972. [Log normal statistics seem well established for saturated conditions.]

723. J. R. Kerr, "Experiments on Turbulence Characteristics and Multi-Wavelength Scintillation Phenomena," JOSA, Vol. 62, No. 9, pp. 1040-1051, September 1972. [Measurements of atmospheric turbulence structure and multiwavelength scintillation statistics are described. The scintillation measurements use coincident virtual point sources, and include log-amplitude variances and covariances, spectra and receiver-aperture smoothing.]

724. J. R. Kerr, Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Final Technical Report 15 June 1972 - 31 August 1973, Rept. No. 1174-4, Oregon Grad. Ctr. for Study & Res., Portland, OR (AD 769 792/3). [The analytical and experimental study of finite-transmitter and wander-tracking effects on target irradiance; and the study of the detailed nature of microthermal turbulence fluctuations, including turbulent intermittency, as related to short-term scintillation statistics.]

725. J. R. Kerr, "Turbulence Effects on Target Illumination by Laser Transmitter: Unified Analysis and Experimental Verificiation," AGARD Conf. Proc. No. 183 Optical Propagation in the Atmosphere, Lyngby, Denmark, 27-31 October 1975 (AD-A028 615). [Mechanisms related to the mean irradiance include diffraction, wander, and wavefront distortion (beam-spread), while irradiance-fading is caused by wander, first-order scintillation, and coherent fading. The phenomenological description unifies the often fragmentary and inconsistent treatment of beam wave phenomena found in the literature, and is sufficiently accurate for engineering purposes.]

726. J. R. Kerr, P. J. Titterton and C. M. Brown, "Atmospheric Distortion of Short Laser Pulses," Appl. Opt., Vol. 8, No. 11, p. 2233, November 1969. [Experiments are described using real time pulse-comparison techniques over a 1.6 km path, with a pulse duration of 1.5 nsec, an optical thickness of 2.8, and a typical angular beamwidth and field of view, pulse distortion was not observed.]

727. J. R. Kerr and J. R. Dunphy, Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Interim Technical Report 1 December 1973 - 30 April 1974, Rept. No. 1103-1, Oregon Grad. Ctr. for Study & Res., Portland, OR (AD 783 277/7). [A unified analytical and phenomenological treatment of the mean irradiance and its fluctuations is presented, with supporting experimental data. A computer simulation technique has been formulated for the generation of an ensemble of instantaneous, short propagation paths through turbulence.]

728. J. R. Kerr, et al., Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, RADC-TR-74-320 (AD-A003 340/7ST). [Model of intermittent turbulence is given and it is shown that the usual mathematical techniques may be applied.]

729. J. R. Kerr, et al., Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Interim Report 1 April 1975 - 31 July 1975, Oregon Grad. Ctr. for Study & Res., Portland, OR (AD-A023 202/5ST). [It is found experimentally that moderately strong scintillations are not described by a bivariate log normal distribution. A study of computer simulation techniques is described which has the goal of making possible realistic models of propagation paths for the short-term, time-dependent statistics of scintillation, including the effects of localized or intermittent strength of turbulence.]

730. J. R. Kerr, et al., Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, RADC-TR-76-49, 1976. [Presents details of calculations given by Lee (JOSA, Vol. 66, p. 1389).]

731. J. R. Kerr, et al., Propagation of Multiwavelength Laser Radiation Through Atmospheric Turbulence, Final Report 1 February - 30 November 1976, Oregon Grad. Ctr. for Study & Res., Portland, OR (AD-A036 503/1ST). [A complete theory is presented for the statistical effects of atmospheric turbulence on coherent radiation reflected from a diffuse target.]

732. J. R. Kerr and J. R. Dunphy, "Experimental Effects of Finite Transmitter Apertures on Scintillations," JOSA, Vol. 63, No. 1, pp. 1-8, January 1973. [Photographic studies for qualitative interpretation of log-amplitude variance, covariance, probability distributions and the spectra of scintillations.]

733. H. V. Khinrikus, A. E. Puro and G. Ye. Tsyhanov, "Parameter Investigation of a Laser Beam Propagating Through a Turbulent Atmosphere," Izv. vuz. Radioelektron, Vol. 17, No. 8, p. 110, August 1974. [Fluctuations of the parameters of a collimated laser beam (λ = 0.63 μm) have been studied over a 5 km urban path, with the object of obtaining information for the design of an optical communications link.]

734. S. S. Khmelevtsov, "Propagation of Laser Radiation in a Turbulent Atmosphere," Appl. Opt., Vol. 12, No. 10, pp. 2421-2433, October 1973. [Influence of laser radiation specificity-space limitation, coherence, broadening of beams, their random wanderings, and intensity fluctuations.]

735. S. S. Khmelevtsov and R. Sh. Tsvyk, Izv. vuz. Radiofiz., No. 1, 1970. [Investigated intensity distribution of 0.6328 μm laser.]

736. S. S. Khmelevtsov and R. Sh. Tsvyk, "Experimental Investigation of Fluctuations in Light Intensity in a Turbulent Atmosphere," Izv. vuz. Radiofiz., No. 6, p. 130, 1973, Trans. in Sov. Phys. J., No. 6. [Measurements are reported of intensity fluctuations in light from a Ne-He laser source over path lengths up to 18.5 km in a turbulent atmosphere. The results are compared with various theoretical estimates currently available.]

737. S. S. Khmelevtsov and R. Sh. Tsvyk, "Intensity Fluctuations and Angle of Arrival of Light Waves in Space-Limited Collimated Beams in a Turbulent Atmosphere," Izv. vuz. Radiofiz., No. 9, p. 108, 1973, Trans. in Sov. Phys. J. [Experimental results are reported for intensity fluctuations and angle of arrival of a laser beam over path lengths between 500 and 700 m.]

738. Y. Kinoshita, T. Asakura and M. Suzuki, "Fluctuation Distribution of Gaussian Beam Propagating Through a Random Medium," JOSA, Vol. 58, No. 6, pp. 798-807, June 1968. [Obtained solution for the variance of log amplitude across the entire beam cross section.]

739. R. H. Kleen and G. R. Ochs, "Measurements of the Wavelength Dependent of Scintillation in Strong Turbulence," JOSA, Vol. 60, No. 12, p. 1695, December 1970 (COM-73-10119-17). [Observations below saturation indicated good agreement with the predicted wavelength dependence. With increasing turbulence, the scintillations for both 0.6328 and 1.084 μm wavelengths saturated at nearly the same level and then decreased, the shorter wavelength tending to decrease more rapidly.]

740. V. Klyatskin, "Applicability of the Approximation of a Markov Random Process in Problems Related to Light in a Medium with Random Inhomogeneities," Sov. Phys. JETP, Vol. 30, pp. 520-523, March 1970.

741. V. Klyatskin and V. I. Tatarski, "The Parabolic Equation Approximation for Propagation of Waves in a Medium with Random Inhomogeneities," Sov. Phys. JETP, Vol. 31, pp. 335-339, August 1970.

742. V. Klyatskin and A. I. Kon, "On the Displacement of Spatially Bounded Light Beams in a Turbulent Medium in the Markovian-Random-Process Approximation," Radiophys. Quant. Electron., Vol. 15, pp. 1056-1061, September 1972. [Beam wander is investigated theoretically using Markovian-random-process approximation.]

743. A. I. Kon, "Focusing of Light in a Turbulent Medium," Radiophys. Quant. Electron., Vol. 13, pp. 43-50, January 1970. [Develops equation for short term irradiance using Huygens-Fresnel principle.]

744. A. I. Kon and V. I. Tatarski, Izv. vuz. Radiofiz., Vol. 7, No. 2, p. 306, 1964. [Investigated strength of source flicker vs. source angular dimension.]

745. A. I. Kon and V. I. Tatarski, "Parameter Fluctuations of a Space-Limited Light Beam in a Turbulent Atmosphere," Izv. vuz. Radiofiz., Vol. 8, No. 5, p. 870, 1965, Trans. in Sov. Radiophys., Vol. 8, No. 5, p. 617, 1965. [Derived expressions for calculating fluctuations in phase and divergence of beam in turbulent atmosphere.]

746. A. I. Kon and V. I. Tatarski, "Theory of Propagation of Partially Coherent Light Beams in a Turbulent Atmosphere," Izv. vuz. Radiofiz., Vol. 10, p. 1547, 1972 (AD-A000 999/3SL). [The function of mutual coherence is considered.]

747. W. L. Kuriger, "Technique for Measuring Laser Beam Proapgation Direction Fluctuations," Appl. Opt., Vol. 10, No. 11, p. 2462, November 1971. [The far-field modulation phase distribution is shown to be relatively unaffected by turbulence, and results are given for a series of experimental measurements of beam-pointing fluctuations.]

748. R. L. Kurtz and J. L. Hayes, Experimental Measurement of Optical Angular Deviation Caused by Atmospheric Turbulence and Refraction, NASA-TN-D-3439, May 1966. [Amplitude and frequency of random position fluctuation for 6 months, paths of 165 and 3200 m, 6328 A laser.]

749. J. P. Laussade and A. Yariv, "A Theoretical Study of Optical Wave Propagation Through Random Atmospheric Turbulence," Radio Sci., Vol. 5, No. 8, p. 1119, August/September 1970 (AD 725 302). [A new method for obtaining exact analytical expressions for some statistical functions of an optical wave propagating through a randomly turbulent medium is reported. The intensity correlation function ($\langle I(L, r_1)I(L, r_2)\rangle$) is investigated, and recent experimental results regarding the behavior of the intensity fluctuations are discussed.]

750. R. S. Lawrence, "Laser-Beam Propagation Through the Clear Turbulent Atmosphere," IEEE J. Quant. Electron., Vol. QE-5, No. 6, p. 328, June 1969. [Details of what happens to the intensity distribution function and the coherence function in the saturation regime, and what special effects may occur at a wavelength of 10.6 μm as a result of the presence of CO_2 in the atmosphere.]

751. R. S. Lawrence, "Irradiance Fluctuations in Optical Transmission Through the Atmosphere," JOSA, Vol. 62, No. 5, p. 701, May 1972. [Briefly discusses failure of Torrieri's heuristic model due to not using the log-normal distribution of irradiance.]

*752. R. S. Lawrence and J. W. Strohbehn, "A Survey of Clear Air Propagation Effects Relevant to Optical Communications," Proc. IEEE, Vol. 58, pp. 1523-1545, October 1970. [Compares existing theories and measurements for variance and probability distributions of intensity, phase and angle of arrival (95 refs.).]

753. J. C. Leader, "Atmospheric Propagation of Partially Coherent Radiation," JOSA, Vol. 68, No. 2, p. 175, February 1978. [Using an extended Rayleigh-Sommerfield integral method, simplifying approximations are made which facilitate closed-form solutions and illustrate the effects of range, propagation angle, source size and coherence, and strength of turbulence on the predicted spatial coherence.]

754. M. H. Lee, "Variance and Covariance of Irradiance of a Finite Beam in Extremely Strong Turbulence," JOSA, Vol. 68, No. 2, pp. 167-169, February 1978. [Extended Huygens-Fresnel formulation of theory. No comparison with measurements.]

755. M. H. Lee, J. F. Holmes and J. R. Kerr, "Statistics of Speckle Propagation Through the Turbulent Atmosphere," JOSA, Vol. 66, No. 11, p. 1164, November 1976. [This analysis of the 1st and 2nd order statistics is based on the extended Huygens-Fresnel formulation; it includes the effect of the turbulent atmosphere on the laser beam path to the target and on the speckle on its return path to the receiver.]

756. M. H. Lee, et al., "Variance of Irradiance for Saturated Scintillations," JOSA, Vol. 66, No. 10, pp. 1389-1392, December 1976. [Shows normalized variance of irradiance approaches unity in the limit of strong turbulence. Uses extended Huygens-Fresnel principle. Compares results with experiments.]

757. R. Lee and J. Harp, "Weak Scattering in Random Media, with Applications to Remote Probing," Proc. IEEE, Vol. 57, pp. 375-406, April 1969. [Rytov does not adequately account for multiple scattering by turbulent eddies.]

758. A. R. Lewis and V. H. Rumsey, "Angular Spectrum Measurements of Atmospheric Turbulence," JOSA, Vol. 67, No. 2, p. 178, February 1977. [A simple experiment was performed, using a rudimentary telescope to receive light from a He-Ne laser (λ = 663 nm) at a distance of 5 km, and photographing the angular spectrum on 35 mm film. Good precision was obtained over a 1000:1 intensity range and the results were in agreement with the Kolmogorov two-thirds law.]

759. P. M. Livingston, et al., "Light Propagation Through a Turbulent Atmosphere: Measurements of the Optical Filter Function," JOSA, Vol. 60, No. 7, pp. 925-935, July 1970. [Irradiance statistics were measured for He-Ne lasers over paths of 650 and 1300 m. Saturation was observed.]

760. V. P. Lukin, et al., "Fluctuation of Phase of Oscillation Modulating the Optical Carriers Propagating in Turbulent Atmosphere," Radio Eng. & Electron. Phys., Vol. 18, No. 3, p. 370, March 1973. [Using the approximation of smooth perturbation, an integral representation is obtained for the variance of phase fluctuation of the harmonic modulating signal at various parameters.]

761. R. F. Lutomirski, "Propagation of Focused Truncated Laser Beams in the Atmosphere," AGARD Conf. Proc. No. 183 Optical Propagation in the Atmosphere, 27-31 October 1975, Lyngby, Denmark. [A formula is derived for the mean intensity distribution from a finite beam in terms of the complex disturbance in the aperture and the mutual coherence function for a spherical wave in the medium.]

762. R. F. Lutomirski and H. T. Yura, "Wave Structure Function and Mutual Coherence Function of an Optical Wave in a Turbulent Atmosphere," JOSA, Vol. 61, No. 4, pp. 482-487, April 1971. [Shows that common expression for wave structure function is in error due to improper extrapolation of Kolmogorov's turbulence spectrum in inertial range.]

763. R. F. Lutomirski and H. T. Yura, On the Phase Structure and Mutual Coherence Function of an Optical Wave in a Turbulent Atmosphere, Rept. No. RM-6266-1-ARPA, Rand Corp., Santa Monica, CA, June 1971 (AD 727 583). [Shows that the most commonly used expression for the mutual coherence function for an optical wave propagating in a turbulence atmosphere is, in general, incorrect. This expression is based on an unphysical extrapolation of the Kolmogorov spectrum.]

764. R. F. Lutomirski and H. T. Yura, "Propagation of a Finite Optical Beam in an Inhomogeneous Medium," Appl. Opt., Vol. 10, pp. 1652-1658, July 1971. [Scintillation phenomena treated by extended Huygens-Fresnel principle. Neglects log amplitude term in perturbation Green's function.]

765. R. F. Lutomirski, et al., Degradation of Laser Systems by Atmospheric Turbulence, Rept. No. R-1171-ARPA/RC (ARPA order #189-1), Rand Corp., Santa Monica, CA, June 1973.

766. P. Mandics, et al., "Spectra of Short-Term Fluctuations of Light-of-Sight Signals: Electromagnetic and Acoustic," Radio Sci., Vol. 8, p. 182, March 1973. [Measured frequency and angle of arrival spectrum in weak and strong turbulence.]

767. J. B. Mason and J. D. Lindberg, Laser Beam Behavior on a Long High Path, Rept. No. ECOM-5430, April 1972 (AD 743 849). [Path is 80 km long and 1.3 km above the surface. Correlations are discussed between temperature lapse rate at the path level and the spreading and deflection of the beam. Beam deflection and beam spread are found to be generally consistent with result obtained by others over lower and shorter paths.]

768. H. C. McDowell and G. H. Stiles, "The Effect of Atmospheric Turbulence on Laser Beam Distribution," Proc. 1st Laser Conf., Vol. II, pp. 73-83, January 1964. [Description of ruby laser experiment at sea level and limited data.]

769. G. E. Mevers, D. L. Fried and M. P. Keister, JOSA, Vol. 55, No. 11, p. 1575, November 1965. [Intensity fluctuations of 0.63 gas laser vs. receiver aperture (3.5 to 50 cm). Verified existence of saturation. Abstract only.]

770. G. E. Mevers, M. P. Keister and D. L. Fried, "Saturation of Scintillation," JOSA, Vol. 59, p. 491, 1969. [Measured super-saturation, shows wavelength dependence after saturation. Abstract only.]

771. G. E. Mevers, M. P. Keister and D. L. Fried, Optical Propagation Measurements at Emerson Lake, 1968, NASA-CR-1733, September 1971 (N71-36755).

772. J. R. Meyer-Arendt and C. B. Emmanuel, Optical Scintillation: A Survey of the Literature, NBS Tech. Note 225, April 1965. [Comprehensive literature survey.]

773. P. O. Minott, "Scintillation in an Earth-to-Space Propagation Path," JOSA, Vol. 62, No. 7, pp. 885-888, July 1972. [A detector aboard the satellite measured the incident light and telemetered the data to recording equipment on the ground, log-amplitude variance, probability distributions, and scintillation frequency distributions are derived from the data.]

774. P. O. Minott, J. L. Bufton and M. W. Fitzmaurice, Results of the Balloon Atmospheric Propagation Experiment Flights of 1970 (Bape 1), NASA-TM-X-65952, March 1972 (N72-28354). [Two laser beams, one argon (5145 Å) and one carbon dioxide (10.6 microns) were propagated over vertical path from the ground to receivers located above the atmosphere, and the scintillation of the beams was measured.]

775. V. L. Mironov and S. S. Khmelevtsov, "Broadening of a Laser Beam Propagating in a Turbulent Atmosphere Along Inclined Routes," Radiophys. Quant. Electron., Vol. 15, pp. 567-571, May 1972, Trans. of Izv. vuz. Radiofiz., Vol. 15, No. 5, pp. 743-750, 1972 (AD-A001 000/9SL). [Calculations are based on the solution of the equation for the coherence function of the second order, obtained in the approximation of a Markov process.]

776. V. L. Mironov and G. Ya. Patrushev, "Field Fluctuations of a Laser Beam Propagated in the Turbulent Atmosphere," Izv. vuz. Radiofiz., Vol. 15, No. 6, p. 865, 1972, Trans. in Radiophys. & Quant. Electron. (AD-A001 222/9SL). [Using the approximating method of smooth perturbations, the variance, correlation, and structural functions of the fluctuations of the logarithm of the amplitude and phase of a laser beam propagating in a turbulent atmosphere were analyzed numerically as a function of the dimensions of the emitting aperture, the focusing radiation conditions, and the coordinates of the observation points in the plane perpendicular to the beam axis.]

777. V. L. Mironov and G. Ya. Patrushev, "Frequency Spectrum of Fluctuations of the Difference Between Amplitudes of Optical Beams Travelling at Different Angles in the Atmosphere," Sov. J. Quant. Electron., Vol. 5, No. 8, p. 942, August 1975. [Approximate integral equations are derived for the frequency spectrum of amplitude differences between laser beams travelling on inclined paths through atmospheric turbulence. Numerical solutions are obtained.]

778. R. L. Mitchell, "Permanence of the Log-Normal Distribution," JOSA, Vol. 58, No. 9, pp. 1267-1272, September 1968. [Distribution of the sum of Log-normal variates is shown in many cases to be log-normal rather than Rayleigh as predicted by central limit theorem.]

779. J. Molyneux, "Propagation of Nth Order Coherence Functions in a Random Medium, II, General Solutions and Asymptotic Behavior," JOSA, Vol. 61, No. 3, pp. 369-377, March 1971. [Generalized Wiener integrals are used to derive the general solutions of the governing equations for all the statistical moments of the radiation field in a random medium. The asymptotic behavior of the solutions are also studied for both large and small values of propagation distance.]

780. R. J. Munick, "Turbulence-Produced Irradiance Fluctuations in Ground-to-Satellite Light Beams," JOSA, Vol. 55, No. 5, p. 594, May 1965. [Estimates of effects of atmospheric turbulence on light beams.]

781. R. J. Munick, "Turbulent Backscatter of Light," JOSA, Vol. 55, No. 7, p. 893, July 1965. [Derived a formula for intensity of light scattered backwards by a turbulent atmosphere. At 0.69 μm this was 5.9×10^{-7} of that by molecular scattering.]

782. G. R. Ochs, "Atmospheric Effects on a Laser Beam in Strong Turbulence," 1969 Annual Meeting of OSA, San Diego, CA, 12 March 1969.

783. G. R. Ochs and C. G. Little, "Studies of Atmospheric Propagation of Laser Beams on 5.5, 15, 45, and 145 km Paths," Conf. on Tropospheric Wave Propag., 30 September - 2 October 1968. [Observations of amplitude scintillations, beam width, and beam wander of laser radiation propagated over long atmospheric paths. He-Ne laser.]

784. G. R. Ochs and R. S. Lawrence, "Saturation of Laser Beam Scintillation Under Conditions of Strong Atmospheric Turbulence," JOSA, Vol. 59, No. 2, pp. 226-227, February 1969. [Measured saturation and super-saturation using He-Ne laser over horizontal 990 n path. Distribution is log-normal.]

785. G. R. Ochs, R. R. Bergman and J. R. Snyder, "Laser Beam Scintillation Over Horizontal Paths from 5.5 to 145 km," JOSA, Vol. 59, pp. 231-234, February 1969. [Measured log amplitude covariance agrees with theory for 5.5 and 15 km paths, but not for 45 km. Also measured turbulence versus altitude well with Hufnagel's model.]

786. P. A. Pincus, et al., "Conditional Fading Statistics of Scintillation," JOSA, Vol. 68, No. 6, p. 756, June 1978. [Field measurements of probability density, two point conditional density and correlation function in weak to strong turbulence.]

787. J. L. Poirier and D. Korff, "Beam Spreading in a Turbulent Medium," JOSA, Vol. 62, No. 7, pp. 893-898, July 1972 (AD 748 530). [Broadening of focused guassian beam is calculated based on modified von Karman spectrum rather than Kolmorogov outside the inertial range.]

788. A. Polushkin, Light Propagation in a Turbulent Atmosphere, Lib. of Congress, Washington DC, Aerospace Tech. Div., 19 March 1969 (AD 684 149). [Presents a comprehensive outline of Soviet research on the propagation of light in a turbulent atmosphere.]

789. D. J. Portman, et al., "Some Optical Properties of Turbulence in Stratified Flow Near the Ground," J. Geophys. Res., Vol. 67, pp. 3223-3235, July 1962. [Optical scintillation measured for 120 and 600 m paths about 1.5 m over both snow and grass. Results related to temperature profiles, wind speeds, Richardson number and path length.]

790. D. J. Portman, E. Ryznar and A. A. Wagif, Laser Scintillation Caused by Turbulence Near the Ground, 1 November 1963 - 30 May 1966, Math Dept., Univ. of Mich., Ann Arbor, MI (AD 666 798). [Laser scintillation was measured for a horizontal optical path 500 m long and 1 m high for various conditions of horizontally homogeneous turbulence, wind direction, average vertical distributions of wind speed and temperature, and, in some cases, turbulent fluctuations of wind velocity were measured simultaneously.]

791. Proceedings of the NATO Expert Conference on Laser Spectroscopy of the Atmosphere, Vol. 8, No. 2, March 1976, 15-21 June 1975, Rjukan, Norway. [The following topics were dealt with: physical properties of the atmosphere including transport and dispersion of atmospheric constituent, turbulence effects, composition and spectral characteristics; instrumentation and techniques in spectroscopic studies of the atmosphere with reference to specific applications; pattern recognition techniques as tools for data analysis.]

*792. A. M. Prokhorov, et al., "Laser Irradiance Propagation in Turbulent Media," Proc. IEEE, Vol. 63, No. 5, pp. 790-811, May 1975. [Results of recent years on propagation in random weakly inhomogeneous media with large scale index of refraction fluctuations are reviewed. Presents analytical models for saturation (127 refs.).]

793. A. M. Prokhorov, et al., "Propagation of Laser Radiation in Randomly Inhomogeneous Media," Sov. Phys. USP, Vol. 17, No. 6, pp. 826-847, May/June 1975. [Analytical methods and experimental data on laser beam propagation are reviewed. In particular the theories of beam spread, intensity fluctuation correlation characteristics and spatial intensity peaks are considered (126 refs.).]

794. B. Querzola and F. Albertin, "Propagation of Laser Beams Through the Atmosphere, II," Alta Freq., Vol. 41, No. 5, p. 350, May 1972. [Theoretical investigation of Maxwell's equations as applied to this problem, and a discussion of the validity of geometrical optics calculations and of Rytov's method.]

795. H. Raidt, "Propagation of Focused Laser Beams in the Turbulent Atmosphere," AGARD Conf. Proc. No. 183 Optical Propagation in the Atmosphere, 27-31 October 1975, Lyngby, Denmark (AD-A028 615). [Experimental results from investigations of instantaneous intensity distributions in focused laser beams at 0.63 μm and 10.6 μm at distances of approximately 1.3 km, 5 km and 8.6 km are presented and discussed.]

796. H. Raidt and D. H. Hohn, "Instantaneous Intensity Distribution in a Focused Laser Beam at 0.63 and 10.6 μm Propagating Through the Atmosphere," Appl. Opt., Vol. 14, No. 11, p. 2747, November 1975. [The measured instantaneous (4 msec - 10 msec) intensity distributions shows that the 0.63 μm beam is broken into several spots but that the 10.6 μm beam pattern remains almost uniform.]

797. T. P. Rankin, Effects of Atmospheric Turbulence on Laser Communications, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1974 (AD 783 815/4).

798. G. W. Reinhardt and S. A. Collins, Jr., "Outer-Scale Effects in Turbulence-Degraded Light Beam Spectra," JOSA, Vol. 62, No. 12, pp. 1526-1528, December 1972. [Extends temporal spectrum calculations to include outer scale effects. Log-amplitude, phase and phase difference spectra have been calculated using the Rytov approximation for both plane and spherical waves.]

799. G. W. Reinhardt and S. A. Collins, Jr., Laser Propagation Temporal Spectra, RADC-TR-73-66, February 1973 (AD 757 915). [The phase difference temporal spectrum was evaluated for arbitrary orientation of the phase observation points in a plane perpendicular to the beam axis. The calculation was based on the method of spectral expansions and the Rytov approximation but the equations were rearranged to emphasize their relationship to the physical picture using a phase screen model.]

800. R. B. Rivir, The Effect of Turbulence on Laser Beam Quality, Final Report March 1973 - August 1976, Rept. No. AFAPL-TR-76-94, AF Aero Propulsion Lab, WPAFB, OH (AD-A038 667/2ST).

801. A. K. Rogers, Laser Beams in Atmospheric Turbulence, A Review, Rept. No. MWC-TP-4752, Naval Weapons Ctr., China Lake, CA, June 1969 (AD 854 747/3ST). [Summarizes the published literature on the interactions of atmospheric turbulence with laser beams.]

802. E. Ryznar, "Dependency of Optical Scintillation Frequency on Wind Speed," Appl. Opt., Vol. 4, pp. 1416-1418, 1965. [Three measurements indicate wind normal to beam is primary determinant for the frequency spectrum of scintillation.]

803. M. Sancer and A. Varvatsis, "Saturation Calculation for Light Propagataion in the Turbulent Atmosphere," JOSA, Vol. 60, No. 5, pp. 654-659, May 1970. [The variance of the irradiance fluctuations is calculated by a method originally proposed by Keller, but is viewed in a conceptually different manner because it leads to solutions whose validity is essentially independent of distance for the coherent field and average energy flux. The calculations in this paper yield a saturation curve that agrees with the experimental data, with a saturation value that depends on both the wavelength and the length of the propagation path.]

804. A. F. Schroeder, Jr., Laser Scintillation Properties in the Marine Boundary Layer, Master's Thesis, Naval Postgraduate School, December 1973 (AD 772 843/9).

805. V. Ya. S'Edin, et al., "Intensity Fluctuations in a Pulsed Laser Beam Propagating Up to 9.8 Km in the Atmosphere," Izv. vuz. Radiofiz., Vol. 13, No. 1, p. 44, 1970, Trans. in Radiophys. Quant. Electron., Vol. 13, pp. 32-35, January 1970. [Measured using ruby lasers over a 9.8 km path, shows significant differences between horizontal and vertical planes.]

806. V. Ya. S'Edin, et al., "Intensity Fluctuations in a Focused Light Beam that Has Passed Through a Stratum of Turbulent Atmosphere," Radiophys. Quant. Electron., Vol. 15, pp. 612-613, May 1972. [Measured intensity fluctuations of ruby lasers (0.63 μm) over paths from 20 to 1360 m.]

807. B. R. Shah, "Optical Communication Atmospheric Effects," JOSA, Vol. 56, No. 4, p. 559, April 1966. [Paper abstract, reviewing the atmospheric effects on a laser beam. Scattering, absorption, beam spreading, beam bending, and low frequency modulation are all mentioned.]

808. O. P. Sharma and S. S. Penner, "Molecular Backscatter of Laser Radiation from Turbulent Air," AIAA J, Vol. 6, No. 10, p. 2035, October 1968. [For detecting clear air turbulence.]

809. H. Shenker, J. A. Dowling and J. A. Curcio, "Propagation of Focused Laser Beams," Proc. of Tech. Prog. Electrical Optical Systems Design Conf. 1971 West, 18-20 May 1971, Anaheim, CA. [Effects of atmospheric turbulence. Preliminary experiments in 0.63 μm and 10.6 μm laser beams conducted over flat, grassy land paths up to 2.2 km in length will be described.]

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811. V. Shishov, "Strong Fluctuations of the Intensity of a Spherical Wave Propagating in a Randomly Reflective Medium," Radiophys. & Quant. Electron., Vol. 15, pp. 689-695, 1972. [Derives integral equation for covariance of spherical wave.]

812. J. F. Spalding and K. Tomiyasu, "Laser Beam Propagation in the Atmosphere," Proc. 1st Laser Conf., Vol. II, pp. 1-12, January 1964. [Limited measurements on turbulence effects in 10 ... ground wind giving modulation vs. beam diameter.]

813. I. Starobinets, "The Average Illumination and Intensity Fluctuations at the Focus of a Light Beam in a Turbulent Atmosphere," Radiophys. Quant. Electron., Vol. 15, pp. 738-742, May 1972.

814. H. W. Straub, "Coherence in Long Range Laser Beams," Appl. Opt., Vol. 4, No. 7, p. 875, 1965. [Vertical beam wander of 6m peak to peak over 3.5 km path have been observed in many localities (temperate, desert, arctic). Horizontal wander never exceeded 30 cm.]

815. J. W. Strohbehn, "Line of Sight Wave Propagation Through the Turbulent Atmosphere," Proc. IEEE, Vol. 56, pp. 1301-1318, August 1968. [Reviews major approximations in theories and discusses recent experimental results on saturation (59 refs.).]

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817. J. W. Strohbehn and S. F. Clifford, "Polarization and Angle-of-Arrival Fluctuations for a Plane Wave Propagating Through a Turbulent Medium," IEEE Trans. Antennas Propag., Vol. AP-15, pp. 416-421, May 1967. [Derives correlation function for the mean square depolarized component.]

818. J. W. Strohbehn and T. I. Wang, "Simplified Equation for Amplitude Scintillations in a Turbulent Atmosphere," JOSA, Vol. 62, No. 9, pp. 1061-1068, September 1972. [This paper is concerned with the amplitude or irradiance scintillations of a wave propagating in a clear turbulent atmosphere.]

819. J. W. Strohbehn, et al., "On the Probability Distribution of Line-of-Sight Fluctuations of Optical Signals," Radio Sci., Vol. 10, pp. 59-70, 1975. [Analytical treatment of probability distribution functions.]

820. V. I. Tatarski, "On Strong Fluctuations of Light Wave Parameters in a Turbulent Medium," Sov. Phys. JETP, Vol. 22, pp. 1083-1088, 1966.

821. V. I. Tatarski, "Light Propagation in a Medium with Random Refractive Index Inhomogeneities in the Markov Random Process Approximation," Sov. Phys. JETP, Vol. 29, pp. 1133-1138, December 1969. [Derived equation; only solutions are for limit for weak turbulence.]

822. M. T. Tavis and H. T. Yura, Short Term Average Irradiance Profile of an Optical Beam in a Turbulent Medium, Rept. No. TR-0077(2608)-1, Aerospace Corp., El Segundo, CA, 28 January 1977 (AD-A035 817/6ST). [The short term average irradiance profile of a focused laser beam transmitted through a homogeneous-isotropic medium has been determined by using the extended Huygens-Fresnel principle and by modifying the phase structure function to remove tilt.]

823. P. B. Taylor, Atmospheric Propagation Studies at Optical, Millimeter, and Microwave Frequencies, Pt. II, The Mechanism of Scintillation, Rept. For 1 January 1964 - 20 January 1965, Dayton Univ., Ohio Res. Inst. (AD 466 031/2ST). [Reviews several explanations which might account for the phenomena.]

824. N. Time, "The Spectrum of the Amplitude Fluctuations in a Bounded Light Beam," Radiophys. Quant. Electron., Vol. 14, p. 936, August 1971. [Obtained approximate expressions for frequency of weak scintillations.]

825. P. J. Titterton, "Wave-Front Curvature and Beam Waist Effects on the Scintillation of Light Beams Directed Upward Through the Atmosphere," 1972 Annual Meeting of OSA, 17-20 October 1972, San Francisco, CA. [A computer analysis is performed, based on Schmeltzer's results. It is found that turbulence at the tropopause significantly reduces transmitter aperture averaging effects as predicted by Fried for collimated beams.]

826. P. J. Titterton, "Scintillation and Transmitter-Aperture Averaging Over Vertical Paths," JOSA, Vol. 63, No. 4, p. 439, April 1973. [Analyzed as a function of turbulence profile. Zenith angle, beam waist at the transmitter, and wave-front curvature at the transmitter, turbulence at the tropopause significantly reduces transmitter-aperture-averaging effects for collimated beams.]

827. P. J. Titterton, et al., Optical Propagation Tests Study, Final Report, April - September 1972, GTE Sylvania, Inc., Mountain View, CA (AD 905 055/OST). [The Optical Propagation Tests Study has analyzed the effects of atmospheric turbulence on atmospheric laser links.]

828. D. J. Torrieri and L. S. Taylor, "Irradiance Fluctuations in Optical Transmission Through the Atmosphere," JOSA, Vol. 62, No. 1, p. 145, January 1972. [Present heuristic model supporting Rayleigh distribution for saturated amplitude scintillations, discounted by Kerr (1972).]

829. R. P. Urtz, Jr., D. O. Tarazano and R. E. Gleba, Amplitude Scintillation Study, RADC-TR-68-416-Vol-1, December 1968 (AD 681 142). [Briefly summarizes available knowledge of scintillation.]

830. R. P. Urtz, A. J. Huber and R. E. Gleba, "Experimental Determination of Phase Structure Function at 10.6 μm," 1971 Annual Meeting of OSA, 5-8 October 1971, Ottawa, Canada. [Measurements have been obtained for a horizontal propagation path of 300 m, approximately 1.5 m above level, grass-covered terrain.

831. R. P. Urtz, A. J. Huber and W. H. Dungey, RADC Laser Propagation Program (for September 1971), RADC-TR-71-252, November 1971 (AD 733 346). [Results are presented of theoretical predictions for the phase structure function for 10.6 micron laser radiation. Experimental data are given for phase structure function measurements for path lengths of 300 meters and a wavelength of 10.6 microns.]

832. A. D. Varvatsis and M. I. Sancer, "Expansion of a Focused Laser Beam in the Turbulent Atmosphere," Can. J. Phys., Vol. 49, No. 10, p. 1233, 16 May 1971. [Formulation is based on Green's theorem and the valid assumption that the turbulent atmosphere is a forward-scatter medium for wavelengths of interest ($0.6 < \lambda < 11\ \mu$).]

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834. M. I. Vorob'ev and A. S. Drofa, "Investigation of the Influence of an External Scale of Atmospheric Turbulence Upon Dispersion of Random Displacements of Light Beams," Radiophys. & Quant. Electron., Vol. 20, No. 11, pp. 1711-1717, 1977. [Procedure and results of measurements of the gravity center displacement of a laser beam in the lowest atmospheric layer along a 355 m horizontal path are presented. The displacement dispersion vs. the outer turbulent scale is investigated.]

835. T. I. Wang and J. W. Strohbehn, "Log-Normal Paradox in Atmospheric Scintillations," JOSA, Vol. 64, pp. 583-591, May 1974. [Shows analytically that neither Rayleigh nor log-normal statistics apply exactly.]

836. W. E. Webb, "Effects of Atmospheric Turbulence on Laser Tracking Systems," Proc. of 8th Annual 1969 IEEE Region III Convention, 19-21 November 1969, Huntsville, AL. [A Kolmogorov spectrum of atmospheric turbulence is assumed and the mean square angle of arrival fluctuations are computed. The theoretical results are shown to agree closely with the available experimental data.]

837. W. E. Webb, Study of Atmospheric Effects on Optical Communications and Optical Systems, Final Report, NASA-CR-102680, November 1969. [Expressions for the magnitude of atmospherically induced angle of arrival fluctuations have been derived. These expressions have been compared with the available experimental data and found to agree within the experimental accuracy.]

838. A. Weigandt and A. V. Appel, "Scintillation Measurements Using a Ground-Aircraft Path," 1972 Annual Meeting of OSA, 17-20 October 1972, San Francisco, CA. [Argon laser beam diameters are typically 30-46 m at altitude. Results for several flights will be presented. The observations fall into two categories, one showing a pronounced time dependence of scintillation level, the other no time dependence; a similar dependence on altitude is apparent.]

839. A. M. Whitman and M. J. Beran, "Asymptotic Theory of Irradiance Fluctuations in a Beam Propagating in a Random Medium," JOSA, Vol. 65, pp. 765-768, 1975. [Does not predict saturation.]

840. M. R. Wohlers, "Approximate Analysis of the Refractive Attenuation of Laser Beam Intensities by Turbulent Absorbing Media," Appl. Opt., Vol. 11, No. 6, pp. 1389-1398, June 1972. [Reasonably simple analytic expressions are obtained for both the transient and the steady-state effects of thermal blooming when the medium is moving relative to the laser beam, and various estimates are also obtained for the turbulence-induced attenuation of the peak intensity of a beam.]

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843. H. T. Yura, "The Mutual Coherence Function of a Finite Cross Section Optical Beam Propagating in a Turbulent Medium," Appl. Opt., Vol. 11, No. 6, pp. 1399-1406, June 1972. [Scintillation phenomena treated by extended Huygens-Fresnel principle.]

844. H. T. Yura, "Optical Beam Spread in a Turbulent Medium: Effect of the Outer Scale of Turbulence," JOSA, Vol. 63, No. 1, pp. 107-109, January 1973 (AD 754 204). [Analytic and numerical results are presented such that the limitations on previous results are obtained.]

845. H. T. Yura, "Short Term Average Optical Beam Spread in a Turbulent Medium," JOSA, Vol. 63, pp. 567-572, 1973. [Develops equation for short term irradiance statistics using Huygens-Fresnel principle.]

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*847. H. T. Yura, "Temporal Frequency Spectrum of an Optical Wave Propagating Under Saturation Conditions," JOSA, Vol. 64, No. 3, p. 357, March 1974. [An expression is derived for the log-amplitude temporal-frequency spectrum of a plane wave propagating in a turbulent medium, which is valid under strong scintillation conditions. Results of analysis agree with those of Tatarski and others.]

848. H. T. Yura, Irradiance Fluctuations of a Spherical Wave Propagating Under Saturation Conditions, Interim Rept., Aerospace Corp. Rept. No. TR-0075(5230-30)-1, El Segundo, CA, 17 December 1974 (AD-A003 406/6ST). [The recent physical model of strong optical scintillation of plane waves is extended to the case of spherical wave propagation.]

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851. L. R. Zintsmaster and S. A. Collins, Jr., Angle of Arrival Calculations at 10.6 Microns, Rept. No. ESL-3163-1, June 1971 (AD 727 798). [A survey of the literature is presented showing two approaches to angle of arrival, one for large aperture receivers and one for a single small aperture or a pair of pinholes. Pertinent defining equations are presented for both cases and values are calculated.]

6. TURBULENCE CONDITIONS

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853. R. Barletti, et al., "Mean Vertical Profile of Atmospheric Turbulence Relevant for Astronomical Seeing," JOSA, Vol. 66, pp. 1380-1383, December 1976. [Model of average refractive index structure coefficient based on 67 radiosonde flights up to 20-25 km in Europe. Compares with models of Hufnagel and Fried.]

854. B. R. Bean, "Turbulence and Irregularities of the Atmosphere," Proc. of NATO Adv. Study Inst., 29 August - 6 September 1969, p. 139, 1970.

855. S. Berman, "Near-Earth Turbulence and Coherence Measurements at Aberdeen Proving Ground, MD," Boundary-Layer Meteorol., Vol. 11, No. 4, p. 485, July 1977. [Turbulence measurements were made at Aberdeen Proving Ground, MD, for five separate 24-hour periods in August, 1971 to obtain data in support of laser beam propagation through the near-earth atmosphere.]

856. J. Bradac, "The Influence of Randomly Changing Medium on the Propagation of E. M. Waves at High Frequencies and Particularly in the Optical Range," Sdelovaci Tech., Vol. 24, No. 1, p. 12, January 1976. [Presents relations for evaluation of the refractive index for centimeter radio waves and for optical waves. Discusses the use of statistical models for evaluating the turbulence.]

857. E. Brookner, "Improved Model for Structure Constant Variations with Altitude," Appl. Opt., Vol. 10, No. 8, p. 1960, August 1971. [Index of refractive fluctuations in atmosphere.]

858. J. L. Bufton, et al., "Measurements of Turbulence Profiles in the Troposphere," JOSA, Vol. 62, No. 9, pp. 1068-1070, September 1972. [Temperature structure coefficients were measured with balloon-borne temperature sensors. Data converted to refractive-index-structure coefficients are reported. Results are discussed with reference to possible meteorological origins for turbulence.]

859. F. H. Champagne, et al., "Flux Measurements, Flux-Estimation-Techniques, and Fine-Scale Turbulence Measurements in the Unstable Surface Layer Over Land," J. Atm. Sci., Vol. 34, pp. 515-530, 1977. [Accurate measurements reveal at high wave numbers the temperature spectrum decreases less rapidly than $k^{-11/3}$ law.]

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861. J. H. Corbin, Measurement of Near Sea Surface Turbulence and Possible Wave Influence, Master's Thesis, Naval Postgraduate School, Monterey, CA, September 1977 (AD-A049 951/7ST). [Measurements were made at 3 levels above the sea surface to observe possible wave influence on turbulence parameters.]

862. J. W. Dungey, "The Influence of the Geomagnetic Field on Turbulence in the Ionosphere," J. Atmos. & Terr. Phys., Vol. 8, Nos. 1 & 2, 1956.

863. W. H. Dungey, D. O. Tarazano and J. C. Wyngaard, "Meteorological Measurements of Turbulence Characteristics," 1971 Annual Meeting of OSA, 5-8 October 1971. [The data have been analyzed to produce power spectral curves, correlation curves leading to a value for an outer scale, and values for the temperature structure parameter.]

864. D. L. Fried, "Limiting Resolution Looking Down Through the Atmosphere," JOSA, Vol. 56, No. 10, pp. 1380-1384, October 1966. [Gives semi-empirical model for C_n^2 vs. altitude based on data given by Hufnagel.]

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866. D. L. Fried, "Effects of Atmospheric Turbulence on a Laser Target Illuminator for Space Targets," Proc. Laser Propag. Meeting, MIT Lincoln Lab, Vol. II, October 1969. [A linearized version of a more complicated model for C_n^2.]

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7. FIELD MEASUREMENTS (Molecular & Aerosol Effects)

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901. "Atmospheric Extinction Measurements of a He-Ne Laser," Appl. Opt., Vol. 17, p. 285, 1978.

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903. W. A. Baum and L. Dunkelman, "Horizontal Attenuation of Ultraviolet Light by the Lower Atmosphere," JOSA, Vol. 45, p. 166, 1955. [Photographic spectrometry (.23-.46 μm) on nights: quite smooth variation, except for weak O_2 absorption from 2421 to 2700 Å and sometime SO_2 solution (2800-3150 Å).]

904. M. Bertolotti, et al., "Measurement of Atmospheric Attenuation at 6328 Å," AGARD Conf. Proc. No. 183 Optical Propagation in Atmosphere, 27-31 October 1976, Lyngby, Denmark. [Atmospheric attenuation statistics have been used to study the performance of a stabilized 6328 Å He-Ne laser communication link. The effects of turbulence and atmospheric conditions are also considered.]

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908. K. J. Bignell, F. Saiedy and P. A. Sheppard, "On the Atmospheric Infrared Continuum, JOSA, Vol. 53, No. 4, p. 466, April 1963. [Field measurements of 8-13 μm continuum absorption using sun and Nernst lamp as sources.]

909. V. P. Bisyarin, I. P. Bisyarina and A. V. Sokolov, "Attenuation of 10.6 μm Laser Radiation in Artificial and Real Fog," Radio Eng. & Electron. Phys., Vol. 16, No. 10, p. 1589, October 1971. [Measurements over 15 m and 1.36 km long paths. Dependence of the attenuation at 10.6 μm and 0.63 μm on the meteorological visibility.]

910. V. P. Bisyarin, I. P. Bisyarina, V. K. Rubash and A. V. Sokolov, "Attenuation of 10.6 and 0.63 μm Laser Radiation in Atmospheric Precipiation," Radio Eng. & Electron., Vol. 16, No. 10, p. 1594, October 1971. [Simultaneous measurements in snow, rain and drizzle over a path of 1.36 km. Attenuation at 10.6 μm is larger than at 0.63 μm.]

911. V. P. Bisyarin, I. P. Bisyarina and A. V. Sokolov, "Temporal Distribution of Coefficients of Attenuation of Laser Radiation at 1.63 and 10.6 μm During Propagation in the Troposphere," Radio Eng. & Electron. Phys., Vol. 18, No. 11, p. 1632, November 1975. [For snowfalls the distribution of the attenuation coefficients at 0.63 and 10.6 μm, is compared with the distribution of the coefficients obtained directly from the measurements of attenuation in real conditions.]

912. E. A. Bucher, R. M. Lerner and C. W. Niessen, "Some Experiments on the Propagation of Light Pulses Through Clouds," Proc. IEEE, Vol. 58, No. 10, p. 1564, October 1970 (AD 721 062). [A facility for measuring the spatial and temporal impulse response of a cloud to a pulse of light from a Q-switched ruby laser is described and some experimental results are presented.]

913. E. A. Bucher and R. M. Lerner, "Experiments on Light Pulse Communication and Propagation Through Atmospheric Clouds," Appl. Opt., Vol. 12, No. 10, p. 2401, March 1973 (AD 771 845/5). [The extent of multipath pulse spreading can be shown to be comparable to that predicted from computer simulation models.]

914. C. C. Chen, Attenuation of Electromagnetic Radiation by Haze, Fog, Clouds, and Rain, Rept. No. R-1694-PR, Rand Corp., Santa Monica, CA (AD-A011 642/6ST). [The report assembles, under one cover, the values of aerosol attenuation coefficients of 'atmospheric windows'. Both calculated and available measured values are presented.]

915. Chicago Midway Labs, Univ. of Chicigo, Atmospheric Transmission in the Infrared During Severe Weather Conditions, May 1959 (AD 218 035). [Poorly controlled measurement at 4 μm in freezing rain, sleet, snow.]

916. T. S. Chu and D. C. Hogg, Bell System Tech. J., Vol. 45, No. 2, p. 301, 1966. [Measured absorption of 3.39 μm laser over 2.9 km range under natural conditions: k = 5.5 ± 0.05 db/km. Agrees well with measurements of Edwards & Burch, and Zuyev's cell measurements (but not field).]

*917. T. S. Chu and D. C. Hogg, "Effects of Precipitation on Propagation at 0.63, 3.5 and 10.6 Microns," Bell System Tech. J., Vol. 47, No. 5, pp. 723-759, May 1968. [Presents measurements in fog, rain and snow, and theory (4 fog models, 1 rain model) for both transmission and beam broadening.]

918. J. A. Curcio, "Evaluation of Atmospheric Aerosol Particle Size Distribution from Scattering Measurements in the Visible and Infrared," JOSA, Vol. 51, No. 5, p. 548, May 1961. [Measured aerosol attenuation (0.4 - 2.27 μm); found Angstrom exponent of 1.3 ± 0.6.]

919. J. A. Curcio, Experimental Observations of Forward Scattering of Light in the Lower Atmosphere, Interim Rept. 30 September 1964, NRL, Washington, DC (AD 607 487). [Experimental results from seven measurements on the forward scattering of light by the atmospheric aerosol.]

920. J. A. Curcio, L. F. Drummeter, C. C. Petty, H. S. Stewart and C. P. Butler, "An Experimental Study of Atmospheric Transmission," JOSA, Vol. 43, No. 2, pp. 97-102, February 1953. [An experimental investigation was made to determine the general characteristics of the spectral transmission of the atmosphere in the Washington DC area, in the Central Pacific, and in the Gulf of Mexico. Transmission measurements were made at the wavelengths of approximately 15 of the Hg discharge lines in the interval 2500 Å to 6000 Å. Values of the spectral atmospheric attenuation coefficients have been computed.]

921. J. S. Curcio, G. L. Knestrick and T. H. Cosden, Atmospheric Scattering in the Visible and Infrared, NRL Rept. No. 5567. [Experimental measurements of aerosol extinction.]

922. J. W. Cusack, Extinction of DF Laser Radiation Derived from Outdoor Atmospheric Measurements, RADC-TR-76-333, December 1976 (AD-A035 473/8ST). [2-1 P(8), 2-1 P(9), 3-2 P(8), and the 2-1 P(6) DF lines. The experimental results are analyzed and compared with the latest in-laboratory measurements.]

923. B. Daino, M. Galeotti and D. Sette, "Statistics of Measurements of Atmospheric Attenuation at 6328 Å (Laser Beam)," Rend. Reiunione Assoc. Elettrotec. Ital., Vol. 49, No. 3, 1974. [The statistical measurements of attenuation of a 6328 Å laser beam in the atmosphere, in horizontal propagation carried out over a 90 m path and at the height of the buildings are described.]

924. B. Daino, M. Galeotti and D. Sette, "Statistical Measurement of Atmospheric 6328 Å Attenuation Using a Sequential Laser Transmissometer," Appl. Opt., Vol. 15, No. 4, p. 996, April 1976. [Typical results are shown for transmission in mist, rain, and good conditions.]

925. L. Delbouille and G. Roland, Photometric Atlas of the Solar Spectrum from λ 7498 to λ 12,016, Liege, 1963.

926. V. A. Donchenko, M. V. Kabanov, B. A. Savel'yev and I. V. Samokhvalov, Sov. Phys. J., No. 1, p. 158, 1968. [Laboratory measurements of backscatter of 0.63 and 0.69 μm laser light from artificial fogs and smokes. Field measurements with 1.06 μm laser in natural haze and falling snow.]

927. J. A. Dowling, "Atmospheric Transmission Measurements Using IR Lasers and Fourier Spectroscopy - Techniques, Results and Comparisons to Computer Models," SPIE, Vol. 91, pp. 39-48, 1976. [Results of comparisons between experimental data and computer generated atmospheric transmission predictions are presented and discussed.]

928. J. A. Dowling, K. M. Haught, R. F. Horton, G. L. Trusty and J. A. Curcio, Atmospheric Extinction Measurements at Nd-Yag and DF Laser Wavelengths Performed in Conjunction with the JAN Propagation Tests, June - September 1975, Rept. No. NRL-8058 (AD-A053 271/3ST). [Extensive measurements of atmospheric transmission at several DF laser wavelengths between 3.6 and 4.1 micrometers were obtained as well as measurements at the Nd-Yag laser wavelength of 1.06 micrometers. MIE scattering calculations were performed using the aerosol data and were compared to aerosol extinction values derived from the optical measurements obtained using the 5 km long path. The water vapor dependence of molecular absorption for each of the 22 DF laser lines studied was compared to values obtained during earlier experiments at the Cape Canaveral Air Force Station and to theoretical predictions based on a Hi-TRAN calculation using a line atlas.]

929. J. A. Dowling, et al., Atmospheric Transmission Measurements Using IR Lasers, Fourier Transmission Spectroscopy, and Gas Filter Correlation Techniques, NRL, Washington, DC, March 1977. [Results obtained from three concurrent experiments used to generate a data base appropriate to high resolution transmission model validation are displayed. Laser extinction data, high resolution, long path atmospheric transmission spectra, and path integrated water vapor measurements are reported and discussed.]

930. J. A. Dowling, R. F. Horton, S. T. Hanely and K. M. Haught, "High Resolution Field Measurement of Atmospheric Transmission," SPIE, Vol. 142, p. 25, 1968. [Instrumentation and procedures used in three experiments will be described and selected measurement results will be presented. Application of this information to current infrared atmospheric transmission problems will be discussed together with comparisons of the experimental data to high resolution computer code calculations.]

931. S. C. Duntley, R. W. Johnson and J. I. Gordon, Airborne Measurements of Optical Atmospheric Properties of Southern Germany, AFCRL-72-0255, July 1972.

932. R. G. Eldridge, "Haze and Fog Aerosol Distributions," J. Atm. Sci., Vol. 23, pp. 605-613, 1966. [Spectral attenuation of haze and fogs were measured in the 0.3-10 μm and used to infer size distributions.]

933. L. Elterman, Atmospheric Attenuation Model, 1964, in the Ultraviolet, Visible, and Infrared Regions for Altitudes to 50 Km, AFCRL-64-740, September 1964.

934. L. Elterman, "Aerosol Measurements in the Troposphere and Stratosphere," Appl. Opt., Vol. 5, No. 11, pp. 1769-1776, November 1966. [Light scattering measurements of a searchlight beam give attenuation coefficients at 0.55 μm up to 35 km.]

935. L. Elterman, An Atlas of Aerosol Attenuation and Extinction Profiles for the Troposphere and Stratosphere, AFCRL-66-828, December 1966. [Measured extinction and derived aerosol attenuation at 0.55 μm up to 35 km.]

936. L. Elterman, UV, Visible and IR Attenuation for Altitudes to 50 Km, AFCRL-68-0153, April 1968. [Tabular values of molecular scattering, aerosol extinction and ozone absorption at 22 wavelengths between 0.27 and 4.0 μm as a function of altitude. Aerosol extinction about a factor of 20 greater than 1964 model at high altitudes.]

937. L. Elterman, Vertical-Attenuation Model with Eight Surface Meteorological Ranges 2 to 13 Kilometers, AFCRL-70-0200, March 1970. [Aerosol extinction model at 22 wavelengths between 0.27 and 4.0 μm as a function of altitude.]

938. C. B. Farmer and J. T. Houghton, "Collision-Induced Absorption in the Earth's Atmosphere," Nature, Vol. 209, p. 1341 and 5030, 1966. [Measured nitrogen continuum absorption near 4 μm in the lab and field.]

939. R. W. Fenn, OPAQUE - A Measurement Program on the Optical Atmospheric Properties in Europe, Vol. I - NATO OPAQUE, AFGL-TR-78-0011, 11 January 1978. [Describes experiment and presents some preliminary results.]

940. R. W. Fenn, OPAQUE Data Analysis (tentative title), AFGL-TR-79-___, to be published. [A statistical analysis of visible and IR transmission, meteorological and natural illumination for the winter season (no laser data).]

941. N. V. Galakhov, et al., "Experimental Investigation of the Intensity Fluctuation of Optical Radiation Propagating in the Atmospheric Surface Layer During Precipitation," Atm. & Oceanic Phys., Vol. 12, No. 12, p. 1251, December 1976. [The intensity fluctuations during rain and snow for a divergent and collimated laser beam at 130 m distance are studied. The time frequency spectrum during rain has two maxima caused by turbulence and aerosols the latter being shifted to high frequencies.]

942. M. Galeotti, B. Daino and D. Sette, "Statistical Measurements of 6328 Å Atmospheric Attenuation (Optical Communication)," Appl. Opt., Vol. 16, No. 3, p. 660, March 1977. [Measurements of atmospheric attenuation at 633 nm in Rome (1 year). Results are presented as frequency distributions.]

943. D. M. Gates, "Near Infrared Atmospheric Tranmission to Solar Radiation," JOSA, Vol. 50, No. 12, p. 1299, December 1960. [Measurements of continuum water absorption (.872-2.537 μm).]

944. H. A. Gebbie, W. R. Harding, C. Hilsum, A. W. Pryce and V. Roberts, "Atmospheric Transmission in the 1 to 14 μ Region," Proc. Roy. Soc., Vol. A206, p. 87, 1951. [Extinction measurements (due mainly to aerosols) are presented correlations with humidity and visibility studied in detail.]

945. K. H. George, P. Marrero and W. E. Webb, Atmospheric Effects on Wave Propagation at 10.6 Microns, NASA-TM-X-64513, 30 April 1970 (N70-31644).

946. R. J. Giannaris, G. C. Mooradian and W. R. Stone, CO_2 Coherent Propagation (with Reciprocal Tracking) Through the Marine Boundary Layer, January - June 1976, Rept. No. NELC-TR-1994, Naval Electronics Lab. Ctr., San Diego, CA (AD-A029 718/4ST). [Measurements of attenuation, characterized as signal loss scintillation, characterized as percent modulation, wavefront tilt, characterizes as angle-of-arrival spectra, and coherence, characterized by the angular brightness function, are made through clear air, haze and fog.]

947. A. J. Gibson and L. Thomas, "Ultraviolet Laser Sounding of the Troposphere and Lower Stratosphere," Nature, Vol. 256, No. 5518, p. 561, 14 August 1975. [Measurements made with a ground-based, ultraviolet laser operating in the wavelength range 297-308 nm are reported, which relate to the question of the atmospheric transmission between ground level and about 20 km, and particularly to the contributions of absorption by minor constitutents.]

948. T. J. Gilmartin, Semi-Annual Technical Summary, ARPA/STO Program (U), MIT Lincoln Labs, Lexington, MA, 30 June 1971 (AD 517 645L) (Secret). [An outdoor measurement of CO laser (5-4 P15) propagation.]

949. R. Gruss, "Transmission Experiments by Laser Beams in the Atmosphere," *Laser*, Vol. 1, No. 4, p. 23, December 1969. [Some transmission experiments with laser beams were made in order to allow the study of future use of atmospheric laser short distance systems for data transmission.]

950. R. Gruss, *Propagation and Transmission of Laser Beams in the Atmosphere*, Rept. No. FTZ-A-465-TBR-6, Fernmeldetechnisches Zentralamt, Darmstadt, West Germany, January 1971 (N72-31519). [Atmospheric laser beam propagation and transmission is discussed, and results of experiments are reported.]

951. K. Gullberg and H. O. Lindstrand, *Measurement of CO_2 Laser Radiation Attenuation in the Atmosphere*, Rept. No. FOA-2-C-2565-E3-E4-E6, Res. Inst. of Natl. Def., Stockholm, Sweden, October 1972 (N75-12299/4ST). [Atmospheric attenuation of CO_2 laser beams at 10.6 micrometer wavelength has been recorded during different weather conditions over a 3 km range.]

952. G. P. Gushchin, "Variations in the Optical Thickness of Aerosols in the Atmosphere," *Trans. of Main Geophys. Obs.*, Vol. 105, p. 43, 1960. [Measurdd aerosol attenuation coefficient vs. altitude.]

953. G. P. Gushchin, In collection entitled: "Actinometry and Atmospheric Optics," Gidrometeoizdat, p. 218, 1961.

954. G. P. Gushchin, *Investigation of Atmospheric Ozone*, Gidrometeoizdat, 1963.

955. A. Gutman, et al., *Data Compendium for Atmospheric Layer Propagation Studies Conducted at Cape Canaveral, Fla. on February-May 1977*, Rept. No. NRL-MR-3611, Naval Res. Labs, September 1977 (AD-A050 094/2ST) [An extensive set of aerosol scattering coefficient data is reported for 15 visible wavelengths. Transmission is reported for 15 visible wavelengths. Transmission spectra included in this report were derived on the basis of Fourier transform spectroscopy (He-Ne, Nd-Yag, DF, CO, CO_2).]

956. T. Hasegawa, H. Sato and T. Sakurada, "Study on the Propagation of Carbon Dioxide Laser Beams Through the Atmosphere," *Mem. Def. Acad.*, Vol. 13, No. 2, p. 119, September 1973. [Attenuation characteristics of the laser beams caused by water vapor, rain and fog in the atmosphere are measured and the experimental formulae of attenuation coefficient are derived from this measurement data. The attenuation characteristics are also compared with those of He-Ne laser beams at 0.6328 μm wavelength.]

957. K. M. Haught and J. A. Dowling, "Laser-Calibrated High-Resolution Atmospheric Transmission Measurements," *IEEE J. Quant. Electron.*, Vol. QE-13, No. 9, p. 71, September 1977. [High-resolution infrared absorption spectrum of a five kilometer atmospheric path was measured with a scanning Michelson interferometer. Absolute transmission at several DF laser frequencies was also measured for the same path.]

958. K. M. Haught and J. A. Dowling, "Long-Path High-Resolution Field Measurements of Absolute Transmission in the 3.5 to 4.0 μm Atmospheric Window," Opt. Letters, Vol. 1, No. 4, pp. 121-123, October 1977. [Experimental details are given of a study of absolute atmospheric transmission in the 3.6-4.0 micron region using a DF laser and using the results to normalize relative transmission from a Fourier transform spectrometer. Calculated and measured transmission spectra are plotted over the range 2480-2800 cm^{-1} for a path of 5.1 km with excellent agreement.]

959. E. A. Johnson, R. C. Meyer, R. E. Hopkins and W. H. Mock, "The Measurement of Light Scattered by the Upper Atmosphere from a Searchlight Beam," JOSA, Vol. 29, No. 12, pp. 512-517, December 1939. [Rayleigh scattering from atmospheric gases in the path of an intense searchlight beam has been measured up to heights of 34 km.]

960. S. R. King, D. T. Hodges, T. S. Hartwick and D. H. Barker, "High-Resolution Atmospheric-Transmission Measurements Using a Laser Heterodyne Radiometer," Appl. Opt., Vol. 12, No. 6, pp. 1106-1107, June 1973. [Measured zenith transmission of entire atmosphere at P(20) line of CO_2 laser: 0.41 at 1.9 pr. cm. H_2O, 0.51 at 1.6 pr. cm. H_2O.]

961. Y. K. Kim, "Transmission Characteristics of Laser Light Communications in Water and Atmospheric Media," J. Korean Inst. Electron. Eng., Vol. 8, No. 4, p. 168, October 1971. [Laser light transmitted through one-meter water bath and one-kilometer transmission distances in atmospheric media is detected by method of direct photo-detection. The average attenuation with the conditions of weather is about -25 db, and the average attenuation coefficient of water is about 0.4 m^{-1}.]

962. G. L. Knestrick, T. H. Cosden and J. A. Curcio, "Atmospheric Scattering Coefficients in the Visible and Infrared Regions," JOSA, Vol. 52, No. 9, p. 1010, September 1962. [Measured aerosol coefficient in ten narrow spectral regions between 0.4 and 2.27 μm at the Chesapeake Bay.]

963. T. Kobayasi, M. Jyumonji and H. Inaba, "Study of Light Beam Propagation in the Atmosphere by Laser-Radar Techniques Using Raman Scattering and Absorption Spectroscopy," 1971 Intl. Sym. on Antennas & Propag. Summaries of Papers, 1-3 September 1971, Sendai, Japan. [Transmission and absorption properties of the laser beam have been studied.]

964. K. Ya. Kondrat'yev, I. Ya. Badinov, S. V. Ashcheulov and S. D. Andreyev, Atm. & Oceanic Phys., Vol. 1, No. 4, p. 363. [Continuous absorption coefficient field measurements using sun as source.]

965. O. Lillesaeter, Attenuation of a Parallel Beam of Light, Particularly by Snow, Rept. No. SR-2, McGill Univ., Montreal, Canada, April 1965 (AD 615 383). [Attenuation measurements over a 123 m path by falling snow was approximately 18 (db 1/km)/(mmw 1/hr), by rain was only 0.25 (db 1/km)/(mm 1/hr).]

966. P. M. Livingston, "Comparison of Measured 3.8 μm Scattering from Naturally Occuring Aerosols with that Predicted by Measured Particle Size Statistics," Appl. Opt., Vol. 17, No. 5, pp. 818-826, 1 March 1978. [A DF chemical laser was used over a range of 1.5 km in the experiments described.]

967. R. K. Long and D. R. Wortendyke, "Topics in the Propagation of Laser Radiation in the Atmosphere," Proc. 1st Laser Conf., Vol. II, p. 51, January 1964. [Measured absorption at 11522.76 cm^{-1} (He-Ne) vs. altitude and calculated absorption for He-Ne and ruby lasers. Night turbulence correlated with wind speed.]

968. R. K. Long and C. H. Boehnker, Measured Atmospheric Absorption at Ruby Optical Maser Wavelengths, Rept. No. 1641-10, Ohio State Univ. Res. Foundation, Columbus, OH, 1 June 1965 (AD 468 330/6ST). [Atmospheric absorption data is presented for three atmospheric water-vapor lines near 6943 Å as a function of path elevation angle.]

969. M. Migeotte, L. Neven and J. Swenson, The Solar Spectrum from 2.8 to 23.7 Microns, Final Report, Pt. 1, Univ. of Liege, Belgium, 1956.

970. M. Migeotte, L. Neven and J. Swenson, The Solar Spectrum from 2.8 to 23.7 Microns, Final Report, Pt. 2, Univ. of Liege, Belgium, 1957.

971. M. Miler and M. Chomat, "The Effect of Atmospheric Scattering on Optical Beam Intensity at Low Visibility," Trans. in: Jemna Mechanika a Optika (Czeckoslovakia), No. 12, p. 382, 1967, by H. Peck (AD 850 030/8ST). [Scattering in fog was measured using an incoherent GaAs diode emitter in the 900 nm infrared band. A formula for attenuation is given, and other experimental findings, such as the effect of size of moisture droplets, of nonhomogeneous waves of thick fog, and of homogeneous fog cover, are given.]

972. J. T. Miller, Experimental Laser Attenuation in a Snow Environment, Final Report 24 January - 4 September 1977, Rept. No. AEDC-TR-77-99 (AD-A051 586/6ST). [Laser transmission through a snowfield has been measured in a lab experiment (0.6328 and a 10.6 micrometer).]

973. M. Minnaert, G. F. Mulders and J. Houtgast, Photometric Atlas of the Solar Spectrum λ 3612 to λ 8771, Amsterdam, 1940.

974. P. O. Minott, et al., Vertical Laser Beam Propagation Through the Troposphere, NASA-TM-X-70701, April 1974 (N74-28970/3). [The characteristics of the earth's atmosphere and its effects upon laser beams was investigated in a series of balloon borne, optical propagation experiments. These experiments were designed to simulate the space to ground laser link.]

975. S. Miura, Y. Furuhama and M. Fukushima, "Some Problems of CO_2 Laser Wave Propagation Through the Atmosphere," Rev. Radio Res. Labs., Vol. 16, No. 87, p. 577, November 1970. [Available data obtained by several workers are reviewed. Results of their measurements are also reported.]

976. M. Murayama, "Laser Beam Propagation Through Falling Snow," Res. Rep. Nagaoka Tech. Coll., Vol. 7, No. 4, p. 279, December 1971. [The relation between the number of snow fractions per unit volume and the attenuation constant of electromagnetic wave propagation was investigated.]

977. S. Nakajima, T. Abe and Y. Saito, "Propagation of the Laser Light in Snowfall," Electron. & Commun., Vol. 56, No. 8, p. 79. [Attenuation and fluctuation of the laser beam propagating in snowfall are discussed and results have been obtained. Experimental and theoretical.]

978. D. C. O'Shea and L. G. Dodge, "NO_2 Concentration Measurements in an Urban Atmosphere Using Differential Absorption Techniques," Appl. Opt., Vol. 13, No. 6, p. 1481, June 1974. [Absorption coefficients of NO_2 for the wavelengths of a mercury lamp and an argon-ion laser are reported.]

979. W. H. Paik, M. Tebyani, D. J. Epstein, R. S. Kennedy and J. H. Shapiro, "Propagation Experiments in Low-Visibility Atmospheres," Appl. Opt., Vol. 17, No. 6, pp. 899-905, 15 March 1978. [A ruby laser and a holmium laser were used to investigate atmospheric transmission characteristics over a 13.6 km line-of-sight path. Multipath spread was never more than 50-350 nsec and angular spectra had a full cone angle of a few mrad at the most.]

980. P.W. Parish, Shipboard Measurements of 0.6328 Micrometer Laser Beam Extinction in the Marine Boundary Layer, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1976 (AD-A028 450/5ST). [A value on the order to 0.0005/meters was found for the extinction coefficient in clear weather.]

981. W. C. Plake and G. E. Walsh, Laser Propagation Effects Over a Half Mile Path, Rept. No. EG/G-S-416-R, EG & G Inc, Goleta, CA, March 1968 (EGG-1183-2178).

982. O. I. Popov, Optics & Spect., Vol. 3, No. 4, p. 504, 1957. [Measured aerosol attenuation in $\Delta\lambda = 0.313 - 0.546$ and $1.014 - 0.546$ μm bands. The Angstrom exponent was $n = 2$ and 1.2-1.3 respectively.]

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984. Yu. I. Rabinovich, Trans. of Main Geophys. Obs., No. 125, p. 54, 1962.

985. H. Raidt and D. H. Hohn, "Transmission of a GaAs Laser Beam Through the Atmosphere," Appl. Opt., Vol. 12, No. 1, p. 103, January 1973. [Even at median meteorological ranges atmospheric aerosol scattering, not atmospheric turbulence, is the main reason for beam spreading. The probability distribution of the fluctuating intensity generally can be approximated with log-normal distribution functions.]

986. J. S. Randhawa, R. B. Loveland, E. E. Uthe and E. R. Murray, "Lidar Observations of Smoke & Dust Clouds at 0.7 and 10.6 Micron Wavelengths," IEEE '78 Region 6 Conf. Record Electronics for Resource Management, 12-14 April 1978. [Range dependent backscatter and range integrated attenuation were measured using a 1 km horizontal path. Smoke and dust clouds were generated so that they were blown across the observed path by the wind.]

987. D. B. Rensch and R. K. Long, "Comparative Studies of Extinction and Backscattering by Aerosols, Fog, and Rain at 10.6 μ and 0.63 μ," Appl. Opt., Vol. 9, No. 7, pp. 1563-1573, July 1970. [Theoretical calculations using continental, fog, and precipitation aerosol size distribution models are presented for extinction and backscatter coefficients along horizontal propagation paths at sea level. Coefficients are presented for various atmospheric conditions and for wavelengths between 0.34 μ and 10.6 μ. Results are confirmed by comparison with outdoor transmission studies at 10.6 μ and 0.63 μ.]

988. W. T. Roach and R. M. Goddy, "Absorption and Emission in the Atmospheric Window from 770 to 1250 cm^{-1}," QJRMS, Vol. 84, p. 319, 1958. [Quantitative experimental study of 8-13 μm continuum but could not separate aerosol effects.]

989. R. G. Roosen, R. J. Anione and C. H. Klemcke, "Worldwide Variations in Atmospheric Transmission: Baseline Results from Smithsonian Observations," Bull. Am. Meteor. Soc., Vol. 54, No. 4, pp. 307-316, April 1973. [Measured extinction coefficient at number of sites from 1904-1930; 0.4 - 1.2 μm.]

990. K. Sassen, "Backscattering Cross Sections for Hydrometeor's Measurements at 6328 A," Appl. Opt., Vol. 17, No. 5, p. 804, March 1978. [A CW He-Ne laser and receiver located 73 cm from the small scattering volume were used to determine the single particle scattering coefficients for 8 types of hydrometers (raindrops, dendritic aggregates, etc.).]

991. F. I. Shimabukuro, et al., Atmospheric Transmission Measurements at HF and DF Laser Wavelengths Using a Heterodyne Radiometer, Interim Rept., Rept. No. TR-0076(6752)-1, Aerospace Corp, El Segundo, CA, 26 February 1976 (AD-A022 057/4ST). [The field measuremed transmissions at HF lines appear less than that predicted by theoretical considerations, while for the DF lines, the measured and calculated transmissions are consistent.]

992. F. I. Shimabukuro, et al., "Atmospheric Transmission Measurements at HF and DF Laser Wavelengths," Appl. Opt., Vol. 15, No. 5, p. 1115, May 1976. [Measured zenith transmission at the HF $P_2(8)$ line are plotted against precipitable water. Transmission tabulated at the several wavelengths are for conditions designated no aerosol, clear, and hazy.]

993. D. E. Spencer, "Scattering Function for Fogs," JOSA, Vol. 50, No. 6, p. 584, June 1960. [Summarizes angular scattering coefficient measurements in the visible to show all fit single function.]

994. J. L. Streete, "Infrared Measurements of Atmospheric Transmission at Sea Lével," Appl. Opt., Vol. 7, No. 8, pp. 1545-1549, August 1968. [Experimental measurements suggests liquid water absorption reason for discrepancy between his and Yates and Taylor measurements. He got much high transmission (0.56 - 10.7 μm) sea level 25 km path.]

995. J. L. Streete, J. H. Taylor and S. L. Ball, "Near Infrared Atmospheric Absorption Over a 25 km Horizontal Path at Sea Level," Appl. Opt., Vol. 6, No. 3, p. 489, March 1967. [Absorption spectra over 25 km sea level path: 0.68 - 4.8 μm (not reduced to transmission).]

996. Z. G. Sztankay and D. W. McGuire, "Backscatter in Clouds at 0.9 μm and Its Effect on Optical Fuzing Systems," Proc. 7th Laser Conf., Vol. III, p. 15, June 1976. [Measured extinction and backscatter coefficients in cumulus clouds.]

997. J. H. Taylor and H. W. Yates, "Atmospheric Transmission in the Infrared," JOSA, Vol. 47, No. 3, pp. 223-226, March 1957. [Measured over three horizontal paths (1000 ft, 3.4 mi and 10.4 mi) from 0.5 to 15 μm at 10 cm^{-1} resolution (clear, dense fog and snowstorm).]

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8. GENERAL

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JOURNAL AND ORGANIZATIONAL ACRONYMS

Acta Phys. Aust.	Acta Physica Austriaca
Adv. in Geophys.	Advances in Geophysics
Aerosol Sci.	Aerosol Science
AFAL	Air Force Avionics Laboratory
AFCRL	Air Force Cambridge Research Laboratory
AFGL	Air Force Geophysics Laboratory
AFIT	Air Force Institute of Technology
AGARD	Advisory Group for Aerospace Research and Development
AIAA J.	American Institute of Astronautics and Aeronautics Journal
Akad Nauk SSR, seriya Geofiz.	Akademiia Nauk S.S.S.R., seriya geofizicheskii
Am. Ind. Hyg. Assoc. J.	American Industrial Hygiene Association Journal
Amer. Meteor. Soc.	American Meteorological Society
Amer. Mineralog.	American Mineralogy
Amer. Sci.	American Science
Ann. Geophys.	Annals of Geophysics
Appl. Opt.	Applied Optics
Appl. Phys. L.	Applied Physics Letter
ARPA	Advance Research Projects Agency (DoD)
ASL	Atmospheric Sciences Laboratory (Army)
Astrophys. J.	Astrophysics Journal

Atm. & Oceanic Phys.	Atmospheric and Oceanic Physics
Atm. Environ.	Atmospheric Environment
Bell. Syst. Tech. J.	Bell System Technical Journal
Bound. Lay. Meteor.	Boundary Layer Meteorology
BRL	Ballistic Research Laboratories
Can. J. Phys.	Canadian Journal of Physics
ECOM	Electronics Command (Army)
Elec. & Comm.	Electronics and Communications
EMI	EMI (England)
Envir. Sci. Tech.	Environmental Science and Technology
ERIM	Environmental Research Institute of Michigan
FTD	Foreign Technology Division (WPAFB)
GDC	General Dynamics Corporation
GE	General Electric Company
Geochem. & Cosmochem. Acta	Geochemica et Cosmochimica Acta
Geophys. Res. Papers	Geophysics Research Papers
Gerlands Beit Geophys.	Gerlands Beitraege Zur Geophysik
IDA	Institute for Defense Analysis
IRIS	Infrared Information Symposia
IR Phys.	Infrared Physics
ITT	International Telephone and Telegraph
J. Aeros. Sci.	Journal of Aerosol Sciences
J. Air Poll. Cont.	Journal of Air Pollution Control
J. Atm. Sci.	Journal of Atmospheric Sciences
J. Atm. & Terr. Phys.	Journal of Atmospheric and Terrestrial Physics
J. Colloid. Inter. Sci.	Journal of Colloidal and Interface Science
J. Geophys. Res.	Journal of Geophysical Research

J. Kor. Inst. Elec. Eng.	Journal of the Korean Institute of Electronic Engineering
J. Meteor.	Journal of Meteorology
J. Mol. Spect.	Journal of Molecular Spectroscopy
JOSA	Journal of the Optical Society of America
J. Phys. Chem.	Journal of Physical Chemistry
J. Phys. Ocean.	Journal of Physical Oceanography
JQRST	Journal of Quantitative Spectroscopy and Radiative Transfer
J. Quant. Elect.	Journal of Quantum Electronics
J. Res. Atm.	Journal of Research in the Atmosphere
J. Res., NBS	Journal of Research, National Bureau of Standards
LMSC	Lockheed Missile and Space Center
MICOM	Missile Command (Army)
MIT	Massachusetts Institute of Technology
MIT/LL	MIT/Lincoln Laboratory
NADC	Naval Air Development Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBS	National Bureau of Standards
NCAR	National Center for Atmospheric Research
NDRE	Norwegian Defense Research Establishment
NELC	Naval Electronics Laboratory Center
NMSU	New Mexico State University
NOAA	National Oceanographic and Atmospheric Administration
NRL	Naval Research Laboratory
NTIS	National Technical Information Services

NWC	Naval Weapons Center
Opt. Letters	Optics Letters
Opt. & Quant. Elec.	Optical and Quantum Electronics
Oreg. State U.	Oregon State University
OSA	Optical Society of America
OSU	Ohio State University
Planet & Space Sci.	Planetary and Space Sciences
Proc. IEEE	Proceedings of the Institute of Electrical and Electronic Engineering
Proc. Roy. Soc.	Proceedings of the Royal Society
PSI	Physical Sciences, Incorporated
Pure Appl. Geophys.	Pure and Applied Geophysics
RADC	Rome Air Development Center (Air Force)
Radio Sci.	Radio Science
RCA	Radio Corporation of America
RRA	Radiation Research Associates
SAI	Science Applications, Incorporated
Sov. J. Quant. Elect.	Soviet Journal of Quantum Electronics
Sov. Phys. J.	Soviet Physics Journal
Sov. J. Opt. Tech.	Soviet Journal of Optical Technology
Space Res.	Space Research
SPIE	Society of Photo-Optical Instrumentation Engineers
SW Cen. Adv. Stud.	Southwestern Center for Advanced Studies
Stud. Geophys. & Geolog.	Studia Geophysica et Geodaetica
Telecom & Radio Eng.	Telecommunication and Radio Engineering
Trans. Am. Geophys. U.	Transactions of the American Geophysical Union
U. Chi.	University of Chicago

U. Mich.	University of Michigan
WPAFB	Wright Patterson Air Force Base
WRE	Western Research Establishment (Australia)
Zeit fur Meteor.	Zeitschrift fuer Meteorologie